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MAURICE

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Integrated water municipal and regional management strategy and action plans

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Content

1. Scope of this Document

MAURICE - Management of urban water resources in Central Europe facing climate change – aims to strengthen resilience against climate change-related pressures affecting urban water management. Both the long-term decline in groundwater levels and the occurrence of excessive volumes of water over short periods constitute urgent risks that must be addressed through appropriate water management practices. The MAURICE transnational partnership facilitates the joint development of innovative concepts for regional climate change adaptation and promotes the uptake of advanced urban water management tools and measures.

Within the framework of MAURICE, six Action Plans are being developed on the basis of pilot actions implemented in participating cities and regions. These plans are intended to provide a robust foundation for the long-term and sustainable implementation of climate adaptation measures. They are designed to enhance urban resilience against both flooding and prolonged dry periods, including the promotion of rainwater reuse.

This strategy document provides guidance throughout the process of preparing, developing, and implementing Action Plans for urban water management. The Action Plans developed by the MAURICE partners are included in the Annex as demonstration examples.

2. Challenges and Framework

Urban areas are particularly vulnerable to climate change due to their dense populations, extensive infrastructure networks, and reliance on centralised water systems. The increasing impacts of climate change heighten the risk of frequent flooding events alternating with droughts and freshwater shortages. The long-established interaction between natural groundwater systems and artificial water bodies is increasingly being disrupted. As a consequence, cities are facing substantial water management challenges related a.o. to water quality, water availability, and groundwater-induced land subsidence.

The application of the sponge city concept strengthens water management across surface, drainage, and subsurface compartments. Measures designed to absorb, store, and reuse rainwater effectively reduce pressure on conventional drainage systems and improve overall water resilience. Sponge cities integrate blue-green infrastructure and nature-based solutions, including permeable pavements, green roofs, rain gardens, and constructed wetlands, in order to enhance water infiltration, storage, and purification. By replicating natural hydrological processes, sponge cities seek to mitigate urban flooding, improve water quality, and support sustainable rainwater management and reuse, thereby ensuring resilient water resources for urban populations.

Groundwater levels are already decreasing in many aquifers globally. However, groundwater storage is relatively less sensitive to seasonal or multiyear climatic variability than other groundwater linked variables such as recharge and discharge, reacting slower to variation in precipitations events than surface water bodies (Amanambu et al., 2020)[1]. But groundwater storage depletion shouldn't be disregarded due to its resistance to sudden changes. As the authors sums up, storage loss is in fact deleterious for livelihood and ecological sustainability, while

[1] Amanambu, Amobichukwu C. [u. a.]: Groundwater system and climate change: Present status and future considerations, in: Journal of Hydrology, Vol. 589 (2020), Article 125163
https://www.sciencedirect.com/science/article/abs/pii/S0022169420306235

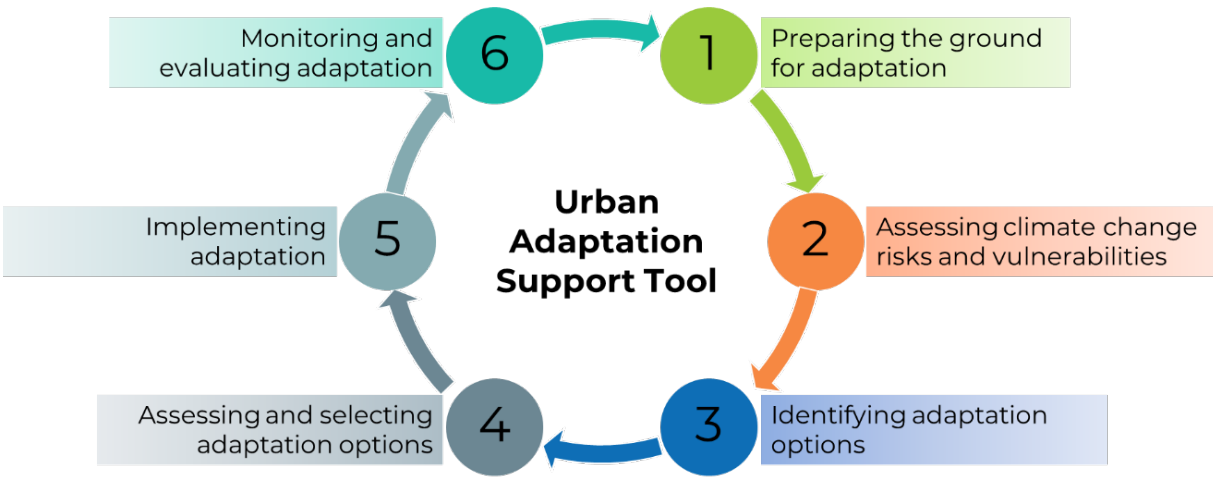
reducing the possible discharge to surface waters as streams and lakes and enhancing the risks of land subsidence due to soil compaction and open spore spaces previously filled with water (Andaryani et al., 2019)[2]. The influence of climate change on groundwater quality may also be associated with increased leaching of contaminants, including pesticides, under warmer climatic conditions. However, both predictions and observations remain subject to considerable uncertainty, as observed impacts may equally be linked to land-use change or increased pest pressure

Without appropriate adaptation measures, urban areas are likely to experience increasing disruption to water services, alongside heightened risks to public health and infrastructure. Adaptation strategies increasingly rely upon highly innovative technical solutions in the fields of modelling and forecasting, hydraulics and civil engineering, aquifer management, water purification and rainwater reuse, as well as spatial planning and urban development linked to sustainable rainwater management.

The objective is to develop proactive measures aligned with ongoing spatial development priorities and emerging regulatory frameworks in the water and planning sectors. Climate-ADAPT, the European Climate Change Adaptation Platform, serves as a comprehensive knowledge hub supporting the EU Mission on Adaptation to Climate Change. It provides up-to-date information on climate trends, adaptation policies, case studies, and practical adaptation measures. Within this framework, the Urban Adaptation Support Tool (UAST) has been developed to support cities, towns, and local authorities in the preparation, implementation, and monitoring of climate adaptation plans.

This strategy is based on the ADAPT support tool, with a particular focus on the methodologies applied and lessons learned within the MAURICE project.

3. Steps to be followed



Urban Adaptation Support Tool (*https://climate-adapt.eea.europa.eu/en/metadata/tools/urban-adaptation-support-tool*)

[2] Nourani, Vahid [u. a.]: Assessment of land use and climate change effects on land subsidence using a hydrological model and radar technique, in: Journal of Hydrology, Vol. 578 (2019), Article 124070 https://www.sciencedirect.com/science/article/pii/S0022169419308054

Regional Adaptation Support Tool
(*https://climate-adapt.eea.europa.eu/en/mission/knowledge-and-data-inactive/regional-adaptation-support-tool*)

3.1. Define Core Questions - Preparing the Ground for Adaptation

3.1.1. Define your Specific Challenge and General Goal

Although climate change (CC) is a global phenomenon, its specific consequences for local and regional water systems vary considerably depending on geographical location, topography, climatic conditions, and related environmental characteristics. Resulting challenges range from drought and water scarcity to frequent flooding, erosion, deterioration in water quality, and land subsidence.

Examples from MAURICE:

- **Stuttgart: Groundwater Management**

  In the urban district of Feuerbach, groundwater levels have declined dramatically in recent years, resulting in significant consequences for extraction rates, building stability, and related infrastructure. The overall objective is to maintain sustainable groundwater resources and stabilise groundwater levels through adaptation to climate change impacts.

- **Milan: Winter Irrigation for Groundwater Recharge**

  The Ticino-Adda groundwater basin is characterized by an extensive historic irrigation network. The increasing alternation between droughts and flood events in recent years necessitates adaptation of the system. The objective is to enhance aquifer storage through off-season (winter) irrigation and/or by maintaining water within the canal system.

- **Jaworzno: Blue-Green Infrastructure**

  Located within a former mining area, Jaworzno faces frequent flooding, land subsidence, and increasing pressure on drinking water, surface water, and groundwater resources. The objective is to reduce vulnerability to sudden flooding events by adapting spatial planning practices and encouraging landowners and residents to implement effective rainwater management solutions.

Photo 1: Examples of land subsidence problem in Jaworzno, Poland

- **Novy Bydzov: Rainwater Reuse**

  Novy Bydzov faces insufficient drinking water capacity due to declining precipitation levels and increasing urban surface sealing. The objective is to collect and reuse rainwater in order to safeguard valuable groundwater resources for drinking water supply.

- **Varaždin: Groundwater Quality Restoration**

  Large-scale hydropower infrastructure along the Drava River has transformed the natural aquifer system into an artificial reservoir, which is additionally affected by nitrate contamination arising from agricultural activities. The objective is to develop a climate adaptation monitoring system capable of supporting both quantitative and qualitative aquifer management, thereby optimizing in situ infiltration processes to improve groundwater quality and reduce nitrate concentrations.

- **Ljubljana: Urban Drainage and Infiltration**

  The objective is to develop technical design solutions for resilient urban drainage systems capable of managing stormwater events while improving groundwater quality. Three principal challenges must be addressed:

  1. Controlling the mass of pollutants entering groundwater;
  2. Controlling the volume of stormwater contributing to groundwater recharge and the way these waters infiltrate the subsurface and reach the groundwater and

3. Reducing the inflow of relatively clean stormwater into the public sewerage system, thereby decreasing environmental pollution caused by frequent combined sewer overflows.

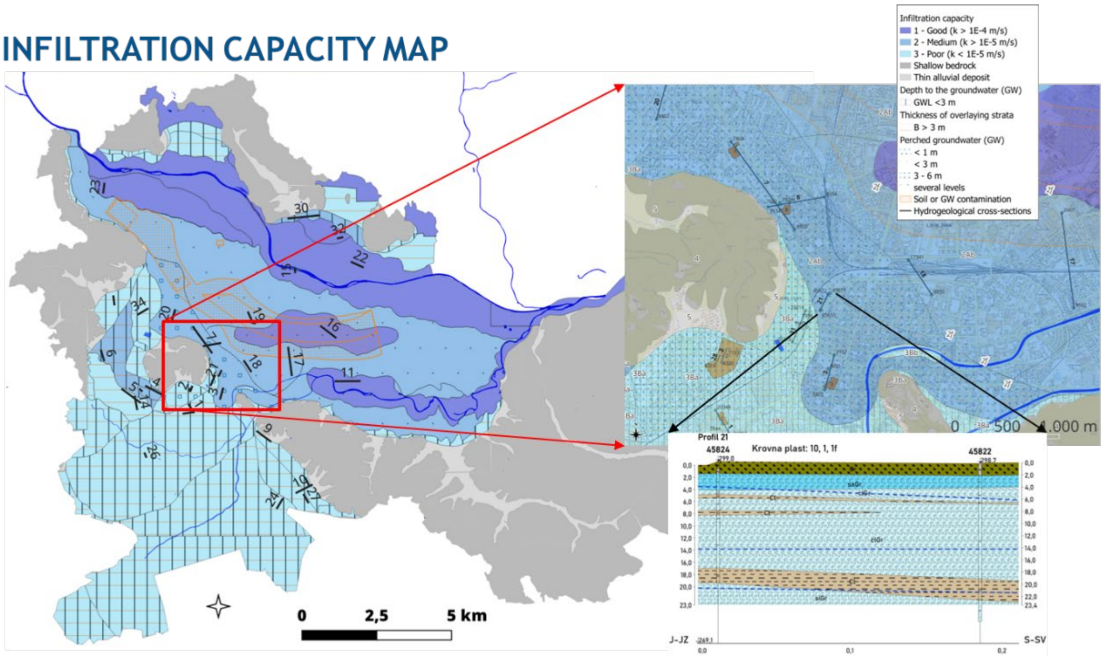


Figure 1. Infiltration capacity map of the City of Ljubljana, showing areas with different infiltration potentials, groundwater depth conditions, and hydrogeological cross-sections, used to support resilient urban drainage design and protect groundwater quality.

3.1.2. Ensure Political Commitment

High-level political support is a prerequisite for the successful implementation of climate adaptation measures within cities and regions. Top-down recommendations, such as the EU Climate-ADAPT Strategy, together with legal requirements at supranational and national levels, frequently act as catalysts for adaptation initiatives. National adaptation strategies may require municipalities to prepare local adaptation strategies and may provide support mechanisms, including financial instruments, to facilitate this process. Within this broader framework, formal decisions securing political commitment and financing should be adopted by local councils or regional governments at an early stage.

Two examples from the MAURICE partnership illustrate this issue:

In **Stuttgart**, the municipal administration acts simultaneously as the local water authority. Responsibilities within the administration vary according to the specific issue concerned and often involve several departments and specialist units operating at different administrative levels. Clear commitment at the level of the mayor and city council can significantly strengthen institutional prioritisation of adaptation measures.

In the **Milan** pilot case, the principal policymaker is the Lombardy Regional Government, which is responsible for regional adaptation strategies, water resource management plans, and agricultural policies. These responsibilities are fundamental to establishing the conditions necessary for the implementation of Ag-MAR as a drought adaptation measure. Equally important, however, is the commitment of farmers' representatives and irrigation consortia, since the adaptation measure directly addresses their operational needs.

3.1.3. Establish a core team

To sustain the adaptation process over the long term, a clear mandate for its management should be assigned to a dedicated organization, department, or specialized working group. The precise responsibilities of the core team will vary according to the local context but may include coordinating the adaptation process within the public authority, preparing policy proposals, serving as a focal point for adaptation issues, and managing both internal and external communication.

Examples from the MAURICE pilot cases in Stuttgart and Milan illustrate differing organizational approaches:

In **Milan,** a context-specific core team facilitated the adaptation process. The team included the Est Ticino Villoresi irrigation consortium, responsible for managing the canal network supplying agricultural areas and cooperating directly with farmers participating in winter irrigation. Politecnico di Milano and the University of Milan contributed scientific and technical expertise to assess the feasibility of Ag-MAR within the study area. The Lombardy Regional Government also participated as an associated project organisation and key policymaker.

In **Stuttgart,** the core team performs a steering and coordination function through the Department of Groundwater Protection and Soil Contamination. As the competent authority responsible for water management, soil protection, nature conservation, energy strategy, and climate-related activities within the city boundaries, the department's involvement in a broad range of planning and approval procedures provides both institutional influence and operational capacity.

3.1.4. Check Legal Obligations

As legal obligations may substantially limit the range of feasible adaptation measures, it is essential to evaluate all relevant legislative requirements. This assessment must adopt a broad perspective, encompassing legal frameworks from the European to the local level, as well as sector-specific legislation relating to urban planning, environmental protection, water management, and property law.

For example, the **Jaworzno** pilot must comply with national regulations relating to construction law, geological and mining law, and environmental protection law, in addition to binding regional and local acts such as building permits and water law provisions. These legal frameworks shape both the Action Plan and the related local regulation issued by the Mayor of Jaworzno concerning Investment Review in Geohazard Areas.

In **Ljubljana,** the project team is conducting an extensive review of water and wastewater legislation. The principal legal and strategic framework for the Action Plan includes the Water Framework Directive, the Groundwater Directive, the Urban Wastewater Treatment Directive, the Drinking Water Supply and Municipal Wastewater Collection and Treatment Act, the Regulation on the Status of Groundwater, the Regulation on the Emission of Substances and Heat from Wastewater Discharges into Waters and Public Sewerage Systems, the Municipal Spatial Plan of the City of Ljubljana – Implementation Part, and the Technical Regulations for Sewerage Systems.

Particular attention is devoted to the Urban Wastewater Treatment Directive, which establishes a direct connection between water resource management and wastewater management through two central objectives: climate change adaptation through stormwater management and strengthening the circular economy through the reuse of treated water.

In this context, it is important to emphasize that the circular economy is future-oriented and should not be interpreted as a continuation of outdated approaches. Its central principle is not the increasingly sophisticated treatment of already polluted water, but rather the timely prevention of discharges, the reduction of disposal requirements, and the interception of substances before they enter the environment. Only through such an approach - reducing pollution at source while maximizing reuse - can the circular economy become an effective framework for sustainable development. It is therefore essential that this principle be clearly communicated at the political level and established as a cornerstone of future environmental policies.

3.1.5. Identify resources, Collect initial information

The core team should begin by undertaking a comprehensive data inventory. Existing studies and assessments relating either to the city itself or to the wider surrounding region may already be available, including climate datasets and statistical records of past weather-related disasters and their impacts. Of particular importance are groundwater and surface water measurements, such as groundwater levels and runoff data, ideally accompanied by long-term historical records covering recent decades.

Existing model simulations may also provide a valuable basis for further work. Consideration should therefore be given to the availability of regional or national climate models suitable for refinement and evaluation. Similarly, it should be determined whether groundwater or surface water modelling has previously been undertaken within the relevant area.

At this stage, opportunities for cooperation with local or regional universities should also be explored. Relevant questions include whether existing research results can be utilised, whether specialised methods or technical tools are available, and whether specific tasks should be delegated to external service providers.

A strong example of such collaboration is provided by **Varaždin**, where the city works closely with the Department of Hydrotechnics at the Faculty of Geotechnical Engineering, University of Zagreb. This cooperation enabled comprehensive data collection and assessment extending back to conditions prior to the construction of the hydroelectric power plants around 1970.

In **Stuttgart,** particular emphasis was placed on methodologies for simulating future climate scenarios using available regional climate models. Taking historical trends in key climatic parameters into account, and building upon published results from the KLIWA collaborative project, projections of future developments, particularly regarding groundwater recharge, were derived. Within the KLIWA project, “Climate Change and Consequences for Water Management”, the federal states of Baden-Württemberg, Bavaria, Hesse, Rhineland-Palatinate, and Saarland, together with the German Weather Service, investigated the effects of climate change on the water cycle, including forecasts concerning soil water balance and groundwater recharge.

3.1.6. Identify stakeholders, local communication approach

As Adaptation is inherently a cross-cutting and cross-sectoral issue, it is relevant to a broad range of stakeholders whose engagement may significantly support adaptation efforts. It is therefore important from the beginning of the planning process to identify the principal stakeholders and understand their interests, responsibilities, and positions in order to develop an effective stakeholder management strategy and thus make the most of their involvement.

A well-designed participatory process is essential in order to involve diverse stakeholders effectively within the climate adaptation planning process. Particular attention should be devoted to transparency, open communication, trust-building, clearly defined responsibilities, and long-term commitment. In addition, a communication strategy should address both internal and external communication requirements while making use of appropriate communication tools and methods.

An important mechanism applied within MAURICE, and previously developed in the AMIIGA project, are the Regional Implementation Groups (RIGs). These groups formally involve the necessary actors and stakeholders within the urban and regional context, including political decision-makers, technical and administrative staff, private landowners and residents, service providers such as water and sewage companies, and urban developers. Establishing a regular meeting schedule supports continuous communication and coordination throughout the adaptation process.

Following the RESIN methodology, stakeholder analysis should be undertaken in order to identify relevant stakeholders and assess their interests, relationships, and positions. This process includes stakeholder identification, categorisation, and the analysis of interactions between stakeholder groups.

Cooperation with relevant stakeholders, including sectoral authorities, interest groups, NGOs, and private sector representatives, may be organized at varying levels of involvement, ranging from information-sharing and consultation to full participatory engagement throughout the process. The level of participation may also evolve during the adaptation process. For example, stakeholders may play a particularly active role in defining objectives while being less directly involved in technical evaluation procedures.

At the beginning of the process, however, both the objectives and the intended role of stakeholders should be clearly defined and communicated in order to manage expectations effectively. All relevant departments and authorities, including those responsible for health, civil protection, transport, energy, economic affairs, finance, and education, should be informed and involved in the adaptation process and provided with an appropriate mandate to make decisions within their respective areas of responsibility. The same principle applies to the core team discussed in Section 3.1.3. Depending on the context, their role may range from information exchange and capacity-building to direct decision-making regarding adaptation measures.

Where possible, existing stakeholder platforms and institutional arrangements should also be utilised. Many cities already possess established participatory structures linked to sustainable development planning, urban development, or spatial planning.

Several important considerations should guide stakeholder involvement:

- Each stakeholder process is unique and therefore requires a diverse set of competencies, including moderation, mediation, and adaptation-related expertise;

- Stakeholder engagement processes are resource-intensive, both financially and organisationally, making early process design essential;
- Briefing materials and meeting minutes should be prepared regularly in order to ensure transparency and continuity of information exchange; and

Stakeholders should be informed regarding the intended use of results and should approve any planned publication where appropriate.

Careful consideration must also be given to the communication methods and messages used for different stakeholder groups and target audiences.

In **Varaždin,** stakeholder coordination could be managed within a relatively streamlined framework due to the project's strong focus on water-related issues. Relevant actors at national and regional level include Croatian Waters and the State Inspectorate of the Republic of Croatia, which is responsible for monitoring and inspecting potential polluters. At the local level, stakeholders include the municipal utility company VARKOM, responsible for water supply and sewerage management; PARKOVI, responsible for green area management; departments of the City of Varaždin involved in legislation concerning blue-green infrastructure, water supply, drainage, and spatial planning; and the technical and business community of planners and designers.

A considerably broader stakeholder network has been assembled in **Ljubljana.** Key stakeholders include the public utility company Vodovod Kanalizacija Snaga, the Ljubljana Urban Planning Institute, the City of Ljubljana – Urban Planning Department, the Urban Planning Institute of the Republic of Slovenia, ZaVita, PNZ Consulting and Design, the Faculty of Civil and Geodetic Engineering – Institute of Public Health Engineering, the Faculty of Civil and Geodetic Engineering – Chair of Geotechnics, the Slovenian Water Agency, the Institute of the Republic of Slovenia for Nature Conservation, the Joint Environmental Protection Service – City of Kranj, and the Geological Survey of Slovenia – Department of Hydrogeology and Groundwater.

Figure 2. Regional Implementation Group workshop in Ljubljana, with representatives from public utilities, municipal and national planning institutions, environmental authorities, and research organisations, supporting the co-creation of the action plan for urban drainage and groundwater protection.

3.2. Assessing Climate Change Risks and Vulnerabilities

3.2.1. Setup of conceptual model

A fundamental step in the development of groundwater- and water-related climate adaptation measures is the establishment of a comprehensive understanding of the local and regional water system. Only a clear understanding of the principal driving forces and interdependencies allows for the identification of specific adaptation needs and parameters.

A preliminary conceptual model should therefore be developed for the area under consideration. This model should describe relevant factors including urban surface sealing, spatial planning requirements, geological, hydrogeological and hydrological conditions, climatic trends, and anticipated future developments. Such information may be presented through explanatory text, thematic maps, graphs, hydrogeological cross-sections, and related visual material. Both quantitative changes, such as groundwater levels and abstraction rates, and qualitative changes, such as nitrate concentrations, should be documented and evaluated.

The process of developing the conceptual model will often reveal existing knowledge gaps and limitations in current understanding. These gaps subsequently define the need for further investigations and additional measurements.

In **Milan,** the project team developed a conceptual model for a pilot area of approximately 12 km × 26 km located between the city of Milan and the Ticino River. The area was selected in order to test and evaluate the feasibility of Ag-MAR within the Adda–Ticino basin. This approach enabled a gradual process of investigation and assessment that ultimately supported the development of a large-scale numerical model.

Stuttgart adopted the reverse approach, beginning with a conceptual hydrological model that identified the principal large-scale water balance parameters required for calibration. Based on this framework, the model was subsequently refined through detailed field measurements and numerical analyses.

3.2.2. Further Investigations and Pilot Actions

Knowledge gaps identified during the conceptual modelling phase must be addressed through additional investigations and measurements. In addition, pilot actions may be implemented in order to test technical solutions and design approaches under real conditions.

In **Milan,** extensive groundwater monitoring campaigns have been undertaken, alongside the installation of a dedicated measurement system for the drainage channel network. Infiltration tests provide essential parameters for simulations of groundwater recharge processes.

The **Jaworzno** pilot adopts a somewhat different approach and places less emphasis on detailed hydrogeological modelling than several of the other pilot areas. Instead, the project focuses on identifying and evaluating best practices in rainwater management. The pilot installation consists of parallel test plots with different surface cover types implemented across the same area. Four experimental platforms enable the selective collection of runoff water and infiltration water. Each platform is equipped with dedicated measurement devices allowing the generation of separate datasets for infiltration and runoff characteristics corresponding to the different surface cover types. The collected water is subsequently utilised within a rain garden that forms an integral component of the pilot infrastructure.

Photo 2: Pilot installation in Jaworzno – permeable surfaces: cavernous concrete, geogrid and mineral-resin pavement.

Photo 3: Pilot installation in Jaworzno – tipping bucket flow measurement system

3.2.3. Data Evaluation - conceptual and numeric models

Following the completion of investigations and additional measurements, the resulting findings should be used to refine and extend the conceptual model. Technical discussions within the expert community support the development of a comprehensive understanding of the present condition of the local or regional water system and its dominant processes.

Data derived from the conceptual model may subsequently be used to establish new numerical models or to expand and improve existing ones in order to simulate hydraulic processes affecting groundwater and surface water systems. Numerical models represent valuable tools both for verifying assumptions underlying the conceptual model and for identifying key driving factors such as temperature, precipitation, surface runoff, and groundwater recharge. Numerical models calibrated against present-day conditions and historical developments can also be used to simulate future scenarios.

For the **Varaždin** aquifer system, a numerical groundwater model has been developed that enables the simulation of a range of CC adaptation scenarios, including the implementation of green and blue infrastructure and in-situ infiltration of roof runoff. The model has also been applied to nitrate transport simulations in order to identify major sources of nitrate contamination within the aquifer. The adaptation objectives in Varaždin include both controlling pollutant loads entering groundwater systems and regulating precipitation infiltration processes contributing to groundwater recharge.

In **Novy Bydzov,** all investigations and sophisticated evaluation and modelling activities ultimately focus on one key question: “Can the use of rainwater reduce groundwater consumption significantly?” The establishment of a comprehensive monitoring network enabled the collection of robust quantitative data relating to the two key indicators, which are

1. Reduction of rainwater run-off, in m3/a
2. Reduction of drinking water consumption, in m3/a.

3.2.4. Climate Models

Information concerning future climatic developments is essential for the assessment of future planning and management options, particularly within the field of water resource management, where uncertainties associated with climate change are expected to exert substantial influence on both short-term and long-term decision-making.

The MAURICE report “Concepts for Prognosis and Assessments of Climate Change Related Pressures on Groundwater” (Deliverable 1.3.1) provides a comprehensive overview and evaluation of available climate models together with methods for downscaling them to the required local and regional scales. Nevertheless, a significant degree of uncertainty remains unavoidable, and planning processes must therefore account for multiple possible future scenarios.

Climate scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) are used to drive Global Climate Models (GCMs). These models mathematically represent physical processes occurring within the atmosphere, oceans, land surfaces, and ice systems, together with the interactions between them. However, for the assessment of local impacts — for example within smaller catchment areas — the spatial resolution of GCMs is generally too coarse.

Accordingly, global climate variables must be downscaled to local scales in order to support impact assessments. The top-down approach involves the downscaling of variables generated by Global Climate Models under a range of emission scenarios through the application of Regional Climate Models (RCMs).

Several techniques are available for downscaling global climate model outputs to higher-resolution regional scales. Among the most widely used are the datasets produced through EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment – European Domain), which provides high-resolution regional climate projections for Europe within the framework of the IPCC Fifth Assessment Report (Jacob et al., 2014)[3].

Considering the impacts of climate change on groundwater systems and surface runoff requires the consideration of numerous factors. The most clearly observable changes concern temperature patterns, precipitation regimes, and atmospheric circulation. Both groundwater and surface water systems are expected to be significantly affected, raising serious concerns regarding future water scarcity and water quality.

In **Ljubljana,** model simulations indicate that regional climate change may alter groundwater flow directions by approximately ±3°. Surface runoff is expected to contribute an increasing proportion of groundwater recharge. Groundwater levels may rise by as much as seven meters in some locations, potentially approaching or reaching building foundations, while at certain abstraction sites groundwater levels may decline by up to two meters.

As the proportion of infiltrating surface runoff increases, combined with greater surface sealing and runoff from built-up and paved areas, the natural retention capacity for pollutants is expected to decline. Similarly, the natural potential for pollutant degradation and dilution may be reduced. Consequently, the previously observed trend of improving water quality between 2000 and 2020 may reverse, leading to deteriorating groundwater quality, a tendency already indicated by monitoring results recorded after 2015.

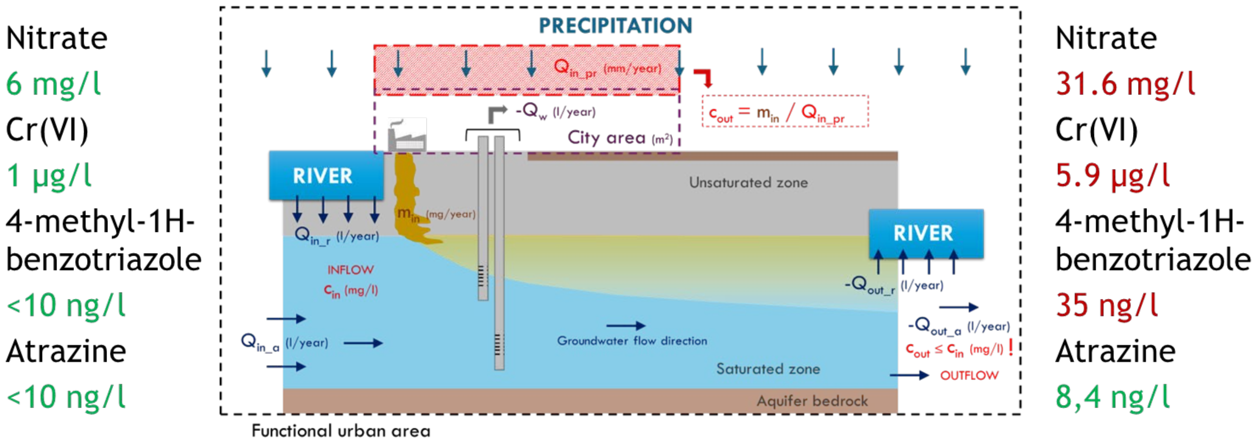


Figure 3. Conceptual representation of climate change impacts on the urban water cycle in Ljubljana, illustrating altered groundwater flow directions, increased surface runoff contribution to groundwater recharge, changes in groundwater levels, and their implications for pollutant transport, dilution capacity, and groundwater quality.

[3] Jacob, Daniela [u. a.]: EURO-CORDEX: new high-resolution climate change projections for European impact research, in: Regional Environmental Change, Vol. 14 (2014), H. 2, pp. 563-578
https://ineris.hal.science/ineris-00963511

In **Varazdin**, climate modelling also indicates clear long-term trends. According to climate models with projections extending to 2070, average air temperatures are expected to increase by approximately 1.5 °C under the RCP2.6 scenario and by more than 2 °C under the RCP8.5 scenario. Precipitation patterns are projected to become increasingly seasonal, with winter precipitation in continental Croatia expected to increase by approximately 5%, while summer precipitation may decrease by between 10% and 20%. Autumn precipitation is projected to vary between +5% and –5%. An increased frequency of extreme precipitation events is likewise anticipated, characterized by high-intensity rainfall capable of generating surface runoff problems, urban flooding, and substantial pressure on public drainage infrastructure.

The hydropower system on the Drava River contributes to relatively stable groundwater levels despite climate change, as the aquifer is primarily recharged by the Drava River. However, climate change is nevertheless expected to reduce groundwater infiltration from precipitation, increase surface runoff, and intensify pressure on public drainage systems.

3.3. Measures and Activities - Identify Adaptation Options

In general, the following categories of adaptation measures can be distinguished:

- Soft adaptation measures, including climate-resilient building design, urban shading measures, and water-sprinkling systems;
- Measures aimed at increasing adaptive capacity through awareness-raising, research activities, monitoring programmes, improved conceptual understanding, supportive institutional frameworks, and the adaptation of legal and technical standards;
- Adaption and refurbishment of grey infrastructure to cope with climate change related challenges like increase capacity of sewage systems, establish or improve flood barriers, control dams; and
- Implementation or extension of (blue-)green infrastructure and nature-based Solutions.

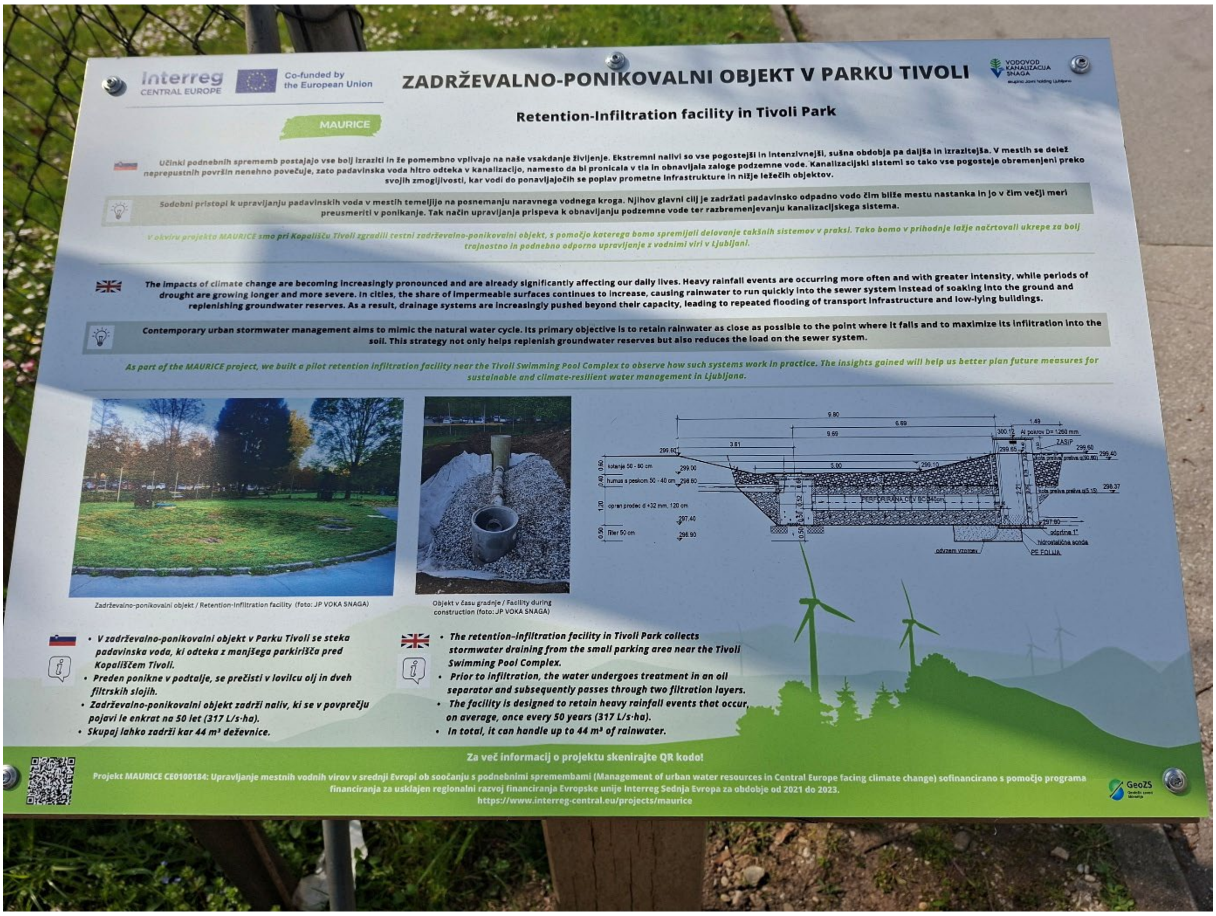


Figure 4. Retention-infiltration facility implemented in Tivoli Park (Ljubljana) as part of the MAURICE project, representing a nature-based solution that combines stormwater retention, infiltration, and pollutant load reduction, while alleviating pressure on the urban drainage system.

Over recent years, numerous catalogues of adaptation measures have been developed by researchers, city networks, national and regional authorities, and stakeholder organisations. These catalogues should serve as a basis for selecting adaptation options appropriate to the specific urban context and corresponding adaptation objectives.

The ADAPT framework provides a digital catalogue of adaptation measures together with a systematic search structure. (https://climate-adapt.eea.europa.eu/en/knowledge/tools/urban-ast/step-3-2).

In addition, the MAURICE report "Analysis of Best Practices in Adaptation to Climate Change" (Deliverable 1.3.2) includes a literature review identifying case studies demonstrating effective adaptation practices relating to groundwater management, stormwater management, and integrated urban water management.

Within groundwater management, much of the existing literature focuses on Managed Aquifer Recharge (MAR) as an approach capable of addressing both water scarcity and drought while simultaneously contributing to the management of stormwater surpluses during heavy rainfall events.

Within the field of stormwater management, sponge city concepts are receiving increasing attention due to their integration of nature-based solutions with grey infrastructure in order to capture, store, and manage rainwater effectively while alleviating pressure on urban drainage systems. Similarly, blue-green infrastructure is increasingly implemented within urban environments both to facilitate infiltration and drainage and to create new opportunities for urban design and spatial planning.

Examples from MAURICE can be categorized in three groups.

In **Jaworzno** and **Novy Bydzov** the primary focus lies on blue-green infrastructure technologies and combinations of nature-based solutions. The MAURICE project has produced Blue-Green Infrastructure Guidelines together with an interactive BGI catalogue providing a systematic overview and generic assessment of potential technical adaptation measures.

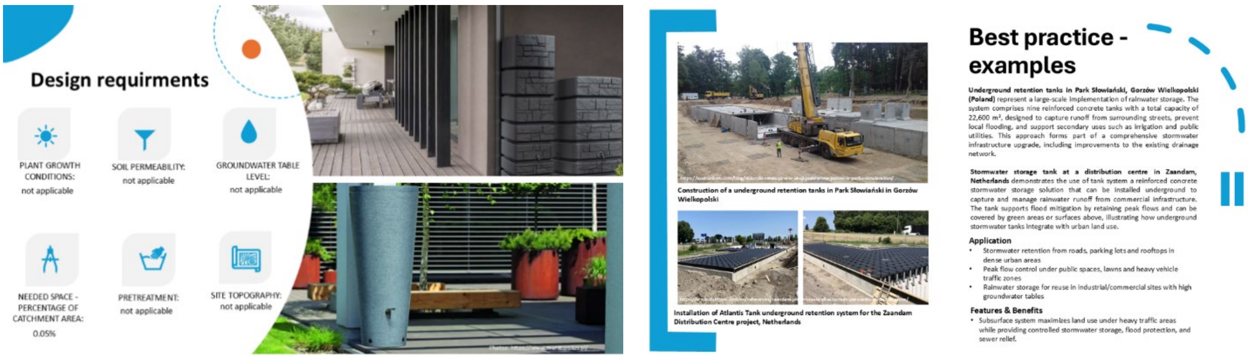


Figure 5. Screenshots of the Guideline for designing blue-green infrastructure for rainwater retention and groundwater recharge

In **Varaždin, Ljubljana** and **Stuttgart** potential adaptation options encompass both technological measures and broader water management solutions. Strategic combinations of measures from both categories offer a wide range of possible interventions.

In Stuttgart, examples of measures designed to enhance rainwater infiltration include:

- (Partial) removal of paving from car parks
- Removal of paving from courtyards
- Greening of street spaces
- Use of water-permeable materials
- Creation of green spaces
- Local infiltration via wells
- Retention and infiltration facilities

The optimal intensity and spatial distribution of such measures must be determined through the application of the developed modelling framework and associated thematic maps, including infiltration capacity maps and subsurface transmissivity assessments.

In **Milan,** one adaptation measure proposed within MAURICE, Ag-MAR, involves aquifer recharge during autumn and winter through the circulation of water within irrigation canals and its infiltration into agricultural land. This approach may function either as a mitigative recharge strategy aimed at restoring groundwater levels following drought events or as a preventive strategy intended to establish strategic water reserves for irrigation during prolonged dry periods. An alternative approach under consideration involves circulating water exclusively through permeable irrigation networks during winter without irrigating agricultural fields directly, thereby achieving a comparable recharge effect. However, additional assessment is required in order to compare these options reliably and evaluate possible synergies between Ag-MAR and wider environmental management activities within Lombardy's integrated water resource management framework.

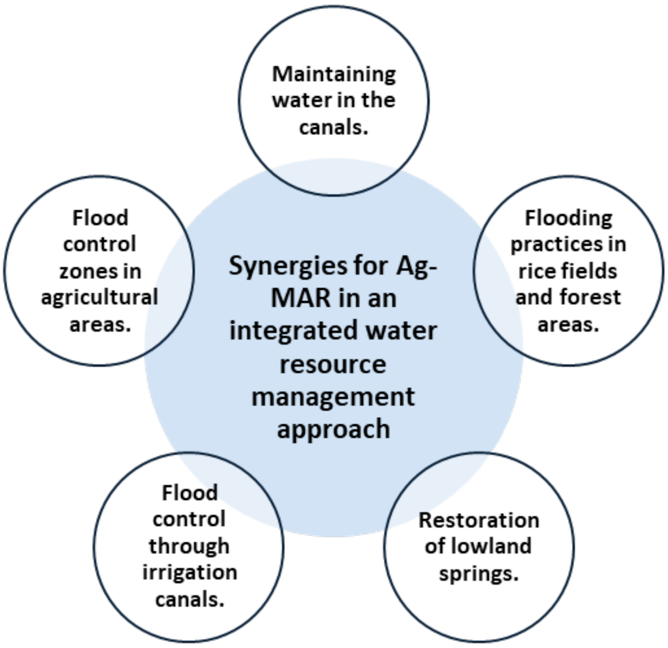


Figure 6. Synergies between Ag-MAR and environmental management activities in Lombardy within an integrated water resources management framework.

3.4. Assessing and Selecting Adaptation Options

Numerical models provide an important basis for simulating and understanding local and regional water systems, including dominant hydrological processes and long-term developments observed over recent decades. Downscaled climate model data, including temperature and precipitation projections, can subsequently be incorporated in order to generate future climate scenarios and evaluate their implications for groundwater levels, surface water discharge, and related parameters.

This evaluation process enables the identification of vulnerabilities together with potential mitigation measures. Within particularly vulnerable areas (for example locations frequently affected by flooding or drought) specific adaptation measures may then be tested and refined.

Appropriate evaluation criteria must also be established in order to assess the effectiveness of adaptation measures. For example, the Milan pilot project, which focuses on artificial groundwater recharge as an adaptation strategy, defined the percentage of water stored within the aquifer and available for future use as a key performance indicator.
The Novy Bydzov pilot, which investigates rainwater treatment and storage technologies, defined the reduction in drinking water consumption in m^3/h as the principal evaluation criterion.

In **Varaždin**, where the principal challenge concerns elevated nitrate concentrations linked to climate change pressures, the objective is to reduce nitrate levels to natural background levels.

The assessment and comparison of adaptation options should include:

- Identification of the risks addressed by each option (each option may effect or treat multiple risks);
- Evaluation of the extent to which each option is expected to reduce identified risks;
- Assessment of the urgency of the climate hazard or risk being addressed.

Some adaptation measures may be implemented rapidly in order to address urgent risks or opportunities, while others may require extensive preparation, planning, and institutional coordination.

The assessment process should also consider broader strategic objectives and avoid maladaptation. Maladaptation occurs when measures fail to achieve their intended objectives or generate negative side effects that hinder adaptation elsewhere or in the future. For example, constructing a dyke in one location may increase flood risk in another area or prove insufficient under future climate conditions.

Some options may be considered to be of incremental or transformative nature. Transformational adaptation involves questioning the effectiveness of existing systems and processes in light of changing circumstances. It is a way of adaptation that changes the fundamental attributes of a system in response to climate and its effects.

Both the direct and indirect economic and environmental consequences of adaptation options should be carefully assessed as part of the overall evaluation process. Measures generating multiple benefits should generally be prioritised, whereas measures that may themselves contribute to climate change or create adverse secondary impacts should be avoided. Consideration should also be given to the interaction between adaptation measures and different societal groups, including the identification of groups that may not benefit equally from the proposed interventions.

Effective adaptation options reduce one or more vulnerabilities to a desired level. Efficient options are those whose benefits exceed their costs and which demonstrate greater cost-effectiveness than available alternatives. Cost-benefit assessments should therefore evaluate whether the anticipated benefits, such as avoided damages or reduced vulnerability, outweigh implementation and operational costs, and to what extent compared with alternative measures. Wherever possible and meaningful, both costs and benefits should be quantified. Where quantification is not feasible, a qualitative assessment shall be delivered. The evaluation process should additionally consider barriers to implementation, including the required financial resources and budget availability, the need for legislative or policy changes, the expected level of stakeholder acceptance as well as the extent of research and development required.

Following the assessment of potential measures, a final selection of the most suitable adaptation options should be undertaken. In many cases, Multi-Criteria Analysis (MCA) provides a particularly effective framework for ranking and selecting preferred options. Stakeholders should be actively involved within MCA processes in order to ensure that differing values, priorities, and perspectives are appropriately reflected in the evaluation.

Such an MCA should include a set of criteria, such as:

- urgency with respect to already existing threats
- early preparatory action (to avoid future damage costs)
- range of effect (options covering multiple risks might be favoured)
- cost-benefit ratio
- efficiency and effectiveness of the measures to deliver adaptation
- socio economic implications for different societal groups
- time-effectiveness
- robustness under a broad range of likely future impacts
- flexibility for adjustments or reversibility in case of diverging developments
- political and cultural acceptability
- enhancement of learning and autonomous adaptive capacity, etc.

When it comes to selecting and prioritising appropriate adaptation options for implementation, it is important to recognise that multiple viable adaptation pathways may exist. Certain options or combinations of options may be better suited to minimising implementation risks while remaining robust under uncertain future climate conditions.

These options are referred to as:

"No-regrets adaptation options" that are worthwhile whatever the extent of future climate change will be;

"Low-regrets options" that are adaptive actions for which the associated costs are relatively low and for which the benefits, although primarily realised under projected future climate change, may be relatively high;

"Win-Win options" are adaptation options that deliver the desired result in terms of minimising the climate risks or exploiting potential opportunities but also have significant contribution to another social, environmental or economic goal;

"Flexible or adaptive management options" are those options that can be adjusted easily (and with low cost), if circumstances change compared to the projections made initially; and "Multiple-benefit options" provide synergies with other goals such as mitigation, disaster risk reduction, environmental management or sustainability (e.g. ecosystem based approaches usually provide such multiple benefits).

Given the uncertainty associated with future climate impacts, no-regret, low-regret, and multiple-benefit measures should generally be favoured. Examples include water-saving technologies in drought-prone regions or improved building insulation in areas increasingly affected by heatwaves. Prioritising options with multiple co-benefits may additionally facilitate access to financing mechanisms by strengthening the broader public value and cost-effectiveness of investments.

The **Milan** example demonstrates clearly that, although Ag-MAR represents the principal drought adaptation measure proposed within MAURICE, additional measures may subsequently be considered for drought-prone agricultural regions in Lombardy. To support future evaluation and evidence-based decision-making, a dedicated set of selection criteria was developed during meetings of the Regional Implementation Group. These criteria reflect the principal dimensions relevant to drought adaptation options within the Lombardy agricultural sector.

	Type	Selection criteria
	Efficiency	• Stored and available water • Reduced drought risk for crop production
	Economic sustainability	• Implementation, operation and maintenance costs
	Environmental impact	• Groundwater level response • Lowland springs benefiting from increased flow
	Social impact	• Stakeholders involved • Farmers involved
	Regulatory feasibility	• Consistency with the regional adaptation strategy and sectorial plans • Compliance with regional water and agriculture regulations

Figure 7. Selection criteria to assess aquifer-based drought adaptation options in Lombardy.

These criteria were assessed for Ag-MAR through two complementary workstreams: i) technical-operational, ii) management and policy.

In **Ljubljana**, the project team involved stakeholders and target-group representatives within the Regional Interest Group in order to identify a broad range of possible adaptation measures. From the perspective of synergies between resilient drainage systems and groundwater protection, the discussion focused on five principal management objectives:

1. enabling groundwater recharge,
2. maintaining groundwater levels,
3. ensuring sufficient dilution of pollutants,
4. balancing surpluses and deficits of water mass,
5. preventing overloading of the sewerage system.

The stakeholder process identified 21 key issues and generated more than 40 guidance measures based on differing technical and institutional perspectives. The principal criterion for including measures within the Action Plan was whether the measure could be considered both effective and feasible at the local level or within existing institutional activities, supported by identifiable funding sources and realistic implementation timeframes.

The most effective and feasible measure identified was the preparation of an infiltration capacity map, including a demonstrative retention-infiltration system designed for areas characterised by limited infiltration capacity. This infiltration capacity map provides a clear overview of expected infiltration potential across different urban zones and identifies the drainage approaches that should be applied within specific spatial planning units or individual building plots. Additional priority measures include managing natural limitations to infiltration, regulating permissible discharges and overflows, and defining critical pollutant concentration thresholds.

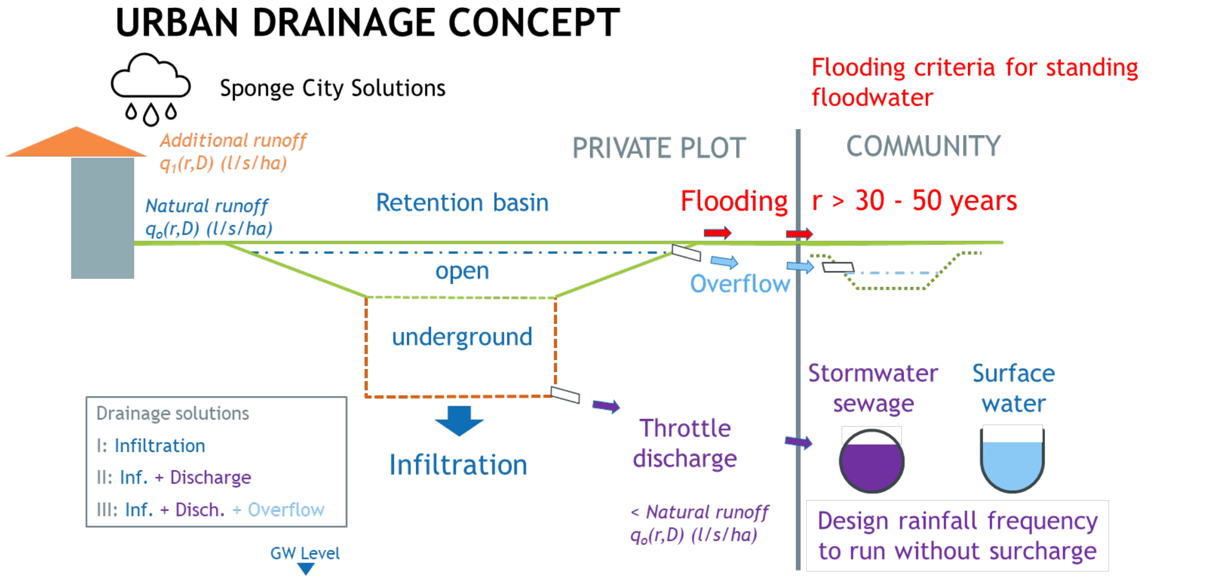


Figure 8. Conceptual drainage scheme illustrating a retention-infiltration system identified through the Ljubljana stakeholder process, showing how local measures can enable groundwater recharge, balance water surpluses and deficits, ensure pollutant dilution, and prevent overloading of the sewer system under design rainfall conditions.

3.5. Action Plan - Implementing Adaptation

The development of a climate change adaptation strategy and action plan involves distinct processes, despite often being used interchangeably.

A strategy acts as a foundational component during the initial phases of policy creation and is crucial for effective implementation. It is characterized as a flexible, medium- to long-term, and non-binding document that encapsulates an organization's vision, adaptation objectives, processes, and recommendations for bolstering adaptive capacity within a specific region.

By contrast, an action plan is developed subsequently and focuses on the practical implementation of the strategic framework. Action plans typically prioritise adaptation measures for shorter implementation periods — often within a five-year horizon — while also identifying responsibilities, financial requirements, and implementation mechanisms. The preparation of an action plan generally requires extensive stakeholder and community engagement, which may introduce additional complexity compared with the broader and more strategic nature of adaptation strategies. In some cases, local or regional authorities may choose to combine both elements within a single integrated document.

At a minimum, adaptation action plans should include the following components:

- Adaptation measures – Outline specific measures processes, and synergies with mitigation efforts and environmental objectives, prioritising different workstreams and identifying trigger points for changes in implementation.
- Roles and responsibilities – Define the roles and responsibilities for coordinating and implementing actions.

- Implementation timeframe – Set a timeline for implementation.
- Financial plan – Estimate the human and financial resources needed, identify available funding schemes, and outline planned investments.
- Monitoring and evaluation – Define indicators aligned with your adaptation objectives and specify responsibilities for monitoring and evaluation.

Adaptation action plans may additionally be organised according to adaptation pathways. Under this approach, the implementation of each adaptation option consists of a sequence of measures designed to achieve a predefined adaptation objective. Each implementation phase represents a distinct building block linked to specific time horizons while simultaneously accounting for uncertainty throughout the implementation process. Adaptation pathways therefore provide a conceptual framework for flexible policy planning and support iterative and dynamic implementation processes capable of responding to uncertainty, managing change within complex socio-ecological systems, and reducing the risk of maladaptation. Adaptation pathways are typically structured around priorities and may resemble decision trees consisting of alternative sequences of actions. Over time, specific tipping points, such as extreme climate events or changes in external framework conditions, may trigger review mechanisms in order to assess whether the current implementation pathway remains suitable for achieving the intended objectives. If necessary, implementation may subsequently shift towards an alternative pathway. When combined with robust monitoring and evaluation mechanisms, this approach can significantly enhance institutional learning processes, increase resilience and strengthen adaptive capacity over time.

The establishment of a reliable implementation schedule closely coordinated with the financial plan is essential, although sufficient flexibility should be retained in order to accommodate adjustments resulting from technical reviews and updated scientific evidence.

Financing mechanisms frequently concentrate on the implementation of individual measures, whereas maintenance costs are often addressed through separate organisational structures or funding streams. Failure to account for maintenance requirements from the outset may result in inadequate long-term financing and operational challenges. Consequently, estimated maintenance costs should be identified during the assessment phase and allocated clearly to the responsible organisational entities.

Mainstreaming adaptation into urban policies, planning procedures, and governance structures should be considered from the earliest stages of the adaptation process. This requires the active involvement of competent municipal departments throughout action planning, including participation in the design and costing of measures. Such an approach facilitates institutional ownership of adaptation measures and improves long-term implementation and maintenance capacity. Ultimately, mainstreaming should ensure that climate adaptation responsibilities become embedded within the regular operational mandates and job descriptions of the relevant departments.

Continuous engagement with stakeholders and citizens throughout implementation is likewise essential, particularly where adaptation measures require public approval or involve potentially sensitive interventions. While some measures may be widely accepted, others, especially those affecting private property rights or land-use practices, may encounter resistance and therefore require sustained communication and stakeholder involvement. Consistent communication strengthens trust, supports constructive relationships, and enhances public acceptance of adaptation measures. Regular cooperation with coordination bodies and advisory committees further ensures alignment with community needs and maintains implementation momentum. Periodic reviews of committee composition and stakeholder participation can also improve effectiveness during the transition from planning to implementation.

In **Milan,** the Consorzio Villoresi intends to utilise the historic irrigation canal network within agricultural areas in order to circulate water during autumn and winter and thereby recharge underlying aquifers. Water is distributed across agricultural fields, where it infiltrates into the soil and replenishes groundwater reserves. The aquifers consequently function as natural underground reservoirs, effectively transforming the surrounding territory into a sponge capable of absorbing and retaining water within the hydrological cycle. This approach avoids many of the economic and environmental costs associated with artificial reservoirs while simultaneously providing additional benefits, including reduced evaporation losses, improved soil conditions, reduced frost damage, and increased irrigation efficiency during subsequent growing seasons.

Successfully implementing Ag-MAR calls for a set of coordinated actions, especially from both the research community and management institutions. On the research side, continued experimentation, monitoring, and analysis will be essential, along with exploring potential mechanisms for service and benefit exchange with farmers and, where relevant, developing sustainability indicators for aquifers. In parallel, the management sector will need to incorporate Ag-MAR into their planning and operational frameworks. Whereas all operational power is with th irrigation consortium Villoresi, an active role is also crucial from the regional government to establish the fundamental conditions for the future feasibility of the measure.

Jaworzno steps into long-term implementation by mainstreaming the adaptation options by the Mayor's regulation set in place for urban development, establishing a formal framework for integrating BGI solutions into municipal decision-making processes, supporting climate change adaptation. A structured investor pathway will be developed to guide private investors in implementing blue-green infrastructure (BGI) solutions, particularly in geohazard areas. The pathway includes step-by-step guidance on investment preparation, required geological and hydrological analyses, and the selection of appropriate BGI solutions using the BGI Guidelines and the interactive catalogue developed within the MAURICE project. Accompanying stakeholder engagement initiatives and a set of educational activities foreseen in the Climate Adaptation Plan shall increase awareness of climate change adaptation and blue-green infrastructure (BGI) solutions among residents, investors and local stakeholders.

Stuttgart provides an advanced example of mainstreaming adaptation through its "Urban Green" funding programme. This programme specifically supports the creation of additional green spaces through financial incentives designed to encourage depaving and greening measures in car parks, courtyards, and entrance areas. In addition to free advisory services, direct financial support is provided for the implementation of adaptation measures. These incentives are closely linked to existing regulations governing sewage and rainwater disposal. For paved surfaces connected to the sewerage network, a rainwater charge of €0.76 per square metre is currently applied. Measures such as green roofs, rainwater storage systems, permeable surfaces, and infiltration facilities reduce this charge and therefore create targeted incentives promoting rainwater infiltration.

All MAURICE partners apply a harmonised table format in order to summarise the principal components of their action plans, see Annex.

Measures		Roles		Timeframe		Finance & Resources		Monitoring	
title	description	Resp.	implement	start	end	manpower	Services & invest	Indicators	Resp.
1									
2									
3									
…									
…									

3.6. Monitoring Concept

The identification and measurement of successful adaptation measures require clearly defined objectives together with associated Key Performance Indicators (KPIs) and baseline values. All project partners prepared concise methodological statements outlining their respective approaches for quantifying the effects of planned measures, defining realistic and appropriate targets, and integrating these elements into their Action Plans.

It is recommended to always define objectives **SMART**: **S**pecific, **M**easurable, **A**chievable, **R**elevant, and **T**ime-bound. Such objectives provide clear guidance for the assessment and selection of adaptation measures, the preparation of action plans, and the evaluation of implementation progress.

These objectives form the basis for the development of an effective monitoring and evaluation framework. A balanced combination of qualitative and quantitative indicators should be applied in order to assess both the direct outputs of adaptation measures and the longer-term outcomes related to resilience-building. It should also be recognised that measurable adaptation outcomes may only become evident after several years.

Quantifiable indicators with clearly defined thresholds are particularly valuable for policymakers because they provide tangible evidence of progress and institutional performance. At the same time, the validation of quantitative data through stakeholder perspectives contributes to a more comprehensive understanding of implementation processes and underlying causal relationships.

Learning from both successful and unsuccessful experiences identified through monitoring and evaluation should form the core of a comprehensive Monitoring, Evaluation, and Learning (MEL) system for climate adaptation processes. Insights generated through monitoring activities should be used continuously to improve adaptation policies and should be shared both internally and externally in order to strengthen collective understanding and institutional learning.

Learning processes should occur throughout the implementation of climate adaptation plans, with a particular focus on refining strategies and introducing corrective measures where necessary in order to achieve intended outcomes. Such learning processes depend upon the continuous incorporation of new information and scientific evidence generated through monitoring and evaluation activities. It is therefore important to establish collaborative learning approaches involving stakeholders through feedback mechanisms such as consultations and participatory review processes.

This participatory approach supports institutional learning while simultaneously ensuring that adaptation measures remain aligned with intended objectives. Active stakeholder engagement also facilitates cross-level learning between regions, municipalities, and communities, thereby strengthening collective understanding of climate risks and adaptation responses. It's important to learn from successes as well as failures to make sure actions are timely, well-targeted and cost-effective.

In Milan post-project monitoring will be based on three key activities:

- Data gathering (through the collaboration with environmental and irrigation managers), processing, and sharing (through the dashboard developed in the MAURICE project).
- Activation of new monitoring points to improve the monitoring network based on the insights from MAURICE.
- Periodic meetings to ensure continuous updates and assessment of Ag-MAR effectiveness.

Based on these elements, a dedicated monitoring centre is envisaged. In addition to overseeing operational activities, this entity would monitor piezometric groundwater levels and determine when Ag-MAR measures should be activated once critical groundwater depletion thresholds are reached.

Table: – Proposed set of monitoring parameters and effectiveness indicators

Monitoring parameters	• Groundwater level
	• Hectares of irrigated agricultural land in the period November–February
	• Kilometres of irrigation canals that carry water year-round
	• Volume of infiltrated water
	• Volume of water distributed to the fields
	• Groundwater and Ticino River quality*
Ag-MAR effectiveness indicators	• % of water actually stored and available for consumption
	• % of demand met
	• % of summer irrigation demand met
	• Number of stakeholders and farmers involved
	• Number of lowland springs benefiting from increased flow

An even more detailed evaluation methodology has been developed in Ljubljana, where comprehensive indicator tables have been established, both for monitoring indicators and evaluation indicators, the latter following as an example for illustration.

Table: Indicators for evaluating adaptation in Ljubljana

ID	Adaptation measures	Evaluation	Value	2027	2028	
1	Constructed retention-infiltration systems	Number				
		Area of drained surfaces				
		Total runoff coefficient Ψm				
		Share of infiltrated stormwater				
2	Drainage solution for the final state of development	Number of spatial planning units				
3	Comparative resilience analysis	Number of spatial planning units				
		Number of building plots				
4	Infiltration of clean roof runoff	Share of roof surfaces infiltrated				
		Share of disconnected roof surfaces				
5	Definition of permitted discharges and overflows	Share of OPN MOL area				
6						
	Groundwater pollutants		**Value**	**2030**	**2035**	
7	Diffuse pollution					
	Nitrate	Concentration (mean-max)				
	Nitrogen	Load				
8	Point-source pollution					
	Hexavalent chromium	Concentration (mean-max)				
		Load				
	Benzotriazoles	Concentration (mean-max)				
		Load				
	Pollutant with a spreading trend	Concentration (mean-max)				
		Load				
9	Implemented measures for critical pollutants	Share of pollutants				

Annexes: Action Plans

Stuttgart

Milan

Jaworzno

Novy Bydzov

Varaždin

Ljubljana

Interreg CENTRAL EUROPE

Co-funded by the European Union

MAURICE

Deliverable D.1.4.1

Action plan Stuttgart

Final version

06 2026

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Definition of Specific Challenge and General Goal

In the Stuttgart-Feuerbach district, in some cases significantly declining groundwater levels have been observed in the near-surface aquifers for approximately 10 to 15 years. This development has adverse effects on non-potable water use, the operation of hydraulic remediation measures, and vegetation. Some existing buildings show settlement damages which could be documented for example in Feuerbach Town Hall.

To mitigate this trend, it is proposed to selectively unseal surfaces like parking areas, courtyards, and street spaces. In addition, it is recommended to reinfiltrate groundwater extracted during groundwater remediation and construction activities. These measures help to increase the infiltration of rainwater and thereby improve water storage in the near-surface aquifers.

Furthermore, continuous groundwater level monitoring at selected monitoring wells in both shallow and deeper aquifers should be carried on. This will allow the ongoing systematic observation of groundwater level trends and enable a reliable assessment of the impacts of climatic changes.

Schützenplatz in Stuttgart

Ensure political commitment

The central stakeholder is the municipal administration of state capital Stuttgart. Within the administration, however, responsibilities differ depending on the specific issue and often involve several departments simultaneously.

For measures of surface unsealing, the planning phase particularly requires the involvement of departments responsible for groundwater protection, contaminated sites/soil contamination, water law, land management, and land-use planning (land-use development plan). During the implementation phase, experts from Civil Engineering and Urban Planning Departments — especially the department responsible for green space planning — are required. However, responsibilities within these municipal offices and expert departments are often divided between different levels of action.

Consequently, complex and time-consuming coordination and decision-making processes involving numerous stakeholders can be expected within the city administration. Nevertheless, the early and comprehensive involvement of all relevant actors is essential to ensure the technically sound and sustainable implementation of the measures.

Check legal obligations

Water management and water protection are facing a range of challenges, in particular with respect to consequences of climate change. To provide a basis for action, the National Water Strategy was published on 15 March 2023. The aim of this strategy is to secure water resources for the future through sustainable water management. One key aspect of this approach is the sustainable management of water resources.

The legal framework governing groundwater interventions is regulated at both federal and state level by the Federal Water Act (Wasserhaushaltsgesetz – WHG of 31 March 2010) and the Water Act for Baden-Württemberg (Wassergesetz – WG of 3 December 2013). These laws include provisions concerning the discharge of substances into groundwater and are therefore also highly relevant for the direct infiltration of rainwater and non-potable water.

In addition, the Groundwater Ordinance (Grundwasserverordnung – GrwV of 9 November 2010) defines the technical basis for the qualitative and quantitative assessment of groundwater bodies.

As a specific regulation for the Stuttgart urban area, the Mineral Spring Protection Ordinance (Heilquellenschutzverordnung of 11 June 2002) must be taken into account. This ordinance defines protection zones with specific prohibitions and restrictions. Due to this regulation, additional site-specific requirements have to be considered to ensure groundwater protection.

Water resources must be protected, and the existing legal framework already provides the basis for sustainable water management. However, Stuttgart’s mineral and therapeutic springs require an even more tailored management approach, as conflicting objectives can only be addressed through differentiated and situation-specific solutions.

Assessing climate change risks and vulnerabilities

A literature review conducted in cooperation with the Italian, Polish, and Slovenian project partners, assessed the current state of knowledge regarding climate scenarios and projections. Report D1.3.1 provides a comprehensive description of the methods used to develop regional and local climate projections, as well as an overview of potential impacts on groundwater and surface runoff.

Following the findings summarized in Report D1.3.1, Report D2.4.1 defines the methodology for simulating future climate scenarios using available regional climate models. In addition, the report analyses historical developments of key climatic parameters such as temperature and precipitation. Based on results of the KLIWA joint project, projections for future developments — especially with regard to groundwater recharge — are derived.

Simulations of the numerical groundwater model are based on results from the KLIWA joint project (“Climate Change and Consequences for Water Management”). In this project, the German federal states of Baden-

Württemberg, Bavaria, Hesse, Rhineland-Palatinate, and Saarland collaborate with the German Meteorological Service to investigate the impacts of climate change on the water balance. One key outcome of the project consists of projections regarding the influence of climatic changes on soil water balance and groundwater recharge. For this purpose, 13 representative future scenarios (WETTREG curves) were selected as part of an audit process.

The developed conceptual and numerical groundwater model integrates all factors relevant to the water balance. Both measured data and model-derived data were integrated, including an extensive existing database available at Stuttgart municipality.

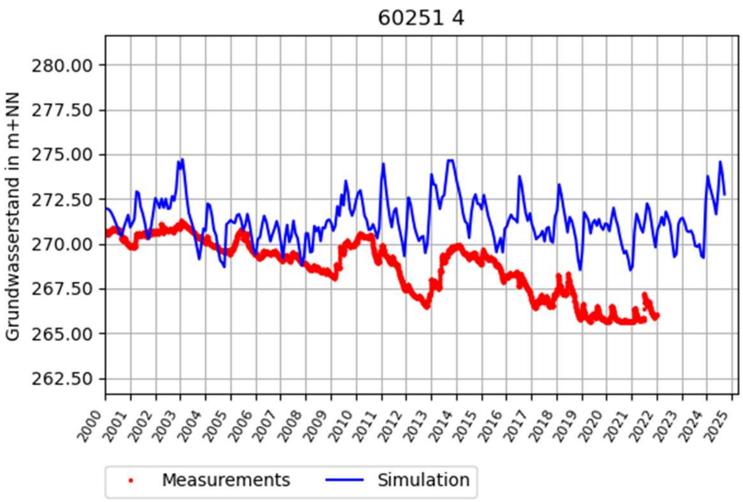
The documentation of the conceptual model is provided in Report D2.2.2, while the numerical groundwater model and the corresponding results are presented in Report D2.2.3.

For the conceptual model, the components of groundwater balance in the Feuerbach area were investigated. All measured and calculable information was incorporated into the groundwater model and analysed.

The soil water balance model for the Feuerbach Valley developed within the MAURICE project (Report D2.2.2) indicates a decline in groundwater recharge of approximately 20% to 25% for the period since the year 2000. These results are consistent with the local estimates provided within the KLIWA joint project.

Based on this magnitude of decline, the observed development of groundwater levels can be reproduced by the numerical model in its essential features. An even closer approximation is achieved by a worst case simulation, assuming a stronger reduction in groundwater recharge of up to 50%. Although this scenario illustrates the sensitivity of the system, it is considered rather unlikely.

It can therefore be concluded that additional influencing factors must play a role. There may be effects of vertical leakage between different groundwater aquifers. Furthermore, local climatic effects that have not yet been sufficiently investigated — for example those associated with a high degree of surface sealing — may also play a significant role.



Measured and simulated hydrographs in the groundwater aquifer Dunkelrote Mergel

Another important observation is the fact, that the total values of annual precipitation have not yet shown a clearly declining trend. However, changes in precipitation patterns can be observed: rainfall events occur less frequently, but are more intense. At the same time, the frequency of extreme events with potential flood impacts is increasing.

Therefore, a direct correlation between reduced groundwater recharge and precipitation trends cannot be established. It must be assumed that local effects, such as increased surface runoff and higher evapotranspiration due to rising temperatures, also contribute to the reduction in groundwater recharge.

Evaluation of numeric groundwater model

The groundwater model Maurice was developed for the complex aquifer system in Stuttgart-Feuerbach. The model was calibrated using measured piezometric heads. However, the quality of the groundwater level time series varies considerably, as many monitoring wells are screened across multiple aquifer levels. Only a limited number of hydrographs are available from wells that can be clearly assigned to a single aquifer.

As a result, the potential for comprehensive calibration across the entire study area was limited. In addition, particularly in forested recharge areas, there is a lack of monitoring wells and long-term hydrograph data. Consequently, the hypothesis of reduced recharge due to climatic conditions could not be verified using long-term observed piezometric heads. This means that no direct validation of trends in hydrological processes and their representation in the model was possible. Only state-wide (Baden-Württemberg) groundwater recharge modelling provided an indication of the magnitude of the current climate-related reduction in recharge, which was incorporated into the hydrological model.

For the hydrological modelling within the Feuerbach catchment, only long-term data from the Schnarrenberg monitoring station, located north of and outside the study area, were available. A comparison with precipitation data from a station within the project area (with a two-year record) showed good agreement in terms of total amounts. However, it remains uncertain whether this agreement also applies to long-term trends and seasonal variability. This introduces uncertainties in the representation of recharge processes by the hydrological model.

Under these conditions, it was challenging to fully reproduce the observed trends, particularly as the observations themselves show varying magnitudes of change. Some of these trends could nevertheless be reproduced for individual monitoring wells. Despite these limitations, the model allowed the magnitude of the missing groundwater inflow to be constrained. A deficit of approximately 10 to 20 L/s was identified as necessary to explain the observed decline in groundwater levels. This conclusion can be considered robust, as falling groundwater levels can only be explained by such a deficit, and the model consistently represents the physical relationship between water balance and piezometric heads.

A key advantage of the modelling approach lies in the ability to analyze potential causes of declining groundwater levels through scenario analysis. The results indicate that a combination of factors is responsible, with climate change being one of them.

Another strength of the model is its application to the evaluation of mitigation measures. Scenario-based analyses made it possible to identify the most effective options for groundwater supply from a hydraulic perspective. However, the practical feasibility of implementing these measures still needs to be assessed.

Further Investigations and Pilot Measures

To provide a general understanding and insight into the characteristics of the pilot area, flow measurements were conducted at the Feuerbach stream, and a hydrological model was developed for the groundwater recharge area in the Feuerbach Valley.

Surface runoff of the Feuerbach stream

In addition, continuous groundwater level recordings were carried out over a period of almost two years at 20 selected and representative monitoring wells using data loggers. Obtained data were integrated into the numerical groundwater model substantiating the existing data fund available for the pilot area.

Transfer of data from data logger

To record meteorological data, an additional weather station was installed in the pilot area for the duration of the project. The collected weather data were compared with data from the German Meteorological Service and were incorporated into the numerical model as well as into the evaluation of the observed groundwater hydrographs.

The model simulated various scenarios to compensate for the missing water volume in the system, in the order of approximately 10 to 20 l/s.

Defined **adaptation objectives were firstly:** achieve an enhanced infiltration, reduce groundwater abstraction and/or foster re-infiltration of extracted groundwater. Secondly, a system for continuous monitoring of groundwater levels was established as a key objective in order to further improve the understanding of the impacts of climate change.

Measures and Activities - Identify Adaptation Options

To compensate for the water deficit identified in the pilot area, the following options were identified:

- Increased infiltration of precipitation into near-surface soil layers
- Local infiltration via wells into deeper aquifers
- Reduction of groundwater abstraction in the context of construction activities
- Re-infiltration of groundwater in the course of construction works and hydraulic remediation measures
- Continuous monitoring of groundwater levels

A key challenge is the amount of inflow required for balancing purposes, of approximately 12–20 l/s. The origin of the required water volumes have to be clarified. In addition, it must be ensured that the planned measures do not cause a mobilisation of potentially existing contaminants in the subsurface.

Assessment of adaptation options

Identified adaptation options were mainly evaluated by numerical model calculations. For increased infiltration, it is necessary to identify suitable areas or, respectively, to specify appropriate sites for infiltration measures.

Infiltration opportunities

In the Feuerbach district, up to 70% of surfaces are sealed. Model calculations show that per km^2 of unsealed area, an increase in groundwater recharge of approximately 6,3 l/s can be expected. To compensate for the currently missing water volume, an unsealing of around 3,5 km^2 would therefore be required.

The following measures are available to increase the infiltration of precipitation:

- (partial) unsealing of parking areas
- Unsealing of courtyards
- greening of street spaces
- use of permeable materials
- creation of green spaces
- local infiltration via wells

For local infiltration via wells, suitable locations must be identified. In the numerical model, a zone with high permeability was delineated in which infiltration via wells appears fundamentally feasible.

Unsealing and installation of permeable paving with full water- and air-permeability at Schützenplatz in Stuttgart.

Requirements and Criteria for Implementation

Before implementing the above-mentioned adaptation options, preconditions have to be checked:

1. **Suitable soil conditions:** The subsurface must have sufficient permeability (kf > 1×10^{-6} m/s).
2. **Contaminant situation in the subsurface:** The potential mobilisation of existing contaminants in the subsoil may conflict with possible infiltration measures.
3. **Groundwater depth:** A sufficient distance between ground surface and groundwater table must be ensured to avoid the risk of waterlogging.
4. **Flood risk:** Infiltration must take place outside flood-prone areas.
5. **Water quality:** The infiltrated stormwater must not contain relevant pollutant loads; pre-treatment may be required if necessary.
6. **Availability of space:** Suitable areas must be available in sufficient quantity.
7. **Legal framework:** All relevant statutory and technical regulations must be complied with.

Increasing infiltration offers a wide range of benefits; however, the following aspects must be considered during implementation:

Environmental impacts:
Enhanced infiltration contributes to increased groundwater recharge and supports the urban water cycle. In addition, it promotes ecological functions, such as improved plant growth and the creation of habitats. At the same time, it can improve the urban climate, particularly through evaporative cooling and the reduction of heat island effects.

Economic impacts:
Infiltration systems require ongoing maintenance efforts. However, there is a potential to save costs arising from a reduced strain on the sewer system, due to lower overload during heavy rainfall events and a decreased risk of flooding.

Initial investment:
Implementation requires initial investments, particularly for the planning and construction of the corresponding systems.

Assessing and Selecting Adaptation Options

The STADTGRÜN tool (stadtgruen-wertschaetzen.de, Institut für ökologische Wirtschaftsförderung) as an available evaluation instrument and can be applied in Stuttgart to quantify the positive effects of additional greening measures. Among other things, it analyses the impact of greening measures on water retention. Its output shows, for example, that increasing the number of street trees or adding green pathways has only a limited effect on water retention. In contrast, expanding connected green spaces leads to a significant improvement in water retention, particularly during heavy rainfall events, along with an increased infiltration of precipitation.

Overall, it becomes clear that large-scale measures are not the only effective approach. Rather, numerous smaller unsealing and greening measures can, in their entity, add a substantial contribution to improving stormwater infiltration.

Implementing adaptation measures

The municipal funding programme “Urban Green” (German: *Urbanes Grün*) provides targeted support when creating additional green spaces. The aim of this programme is to initiate and implement unsealing and greening measures through suitable funding instruments, in particular on parking spaces, in courtyards, and in entrance areas. In addition to free advisory services, financial support is also provided for the implementation of corresponding measures.

The City of Stuttgart supports the unsealing and greening of surfaces through the programme “Urban Green” (*Urbanes Grün*).

In addition, in cooperation with Stuttgart university, a master’s thesis is being initiated with the aim of updating the existing surface sealing map. This map will serve as an important planning basis for identifying suitable areas in public space for unsealing measures —such as parking lots, street spaces, or courtyard areas. The overarching goal of increasing the proportion of green and water areas in the urban territory is also firmly anchored in the city’s climate adaptation strategy.

In Stuttgart, separate regulations exist for the disposal of wastewater and stormwater. For sealed surfaces connected to the sewer system, a stormwater fee of 0.76 euros per square meter is currently charged. Measures such as green roofs, the installation of rainwater harvesting systems (cisterns), the use of permeable paving materials, and the creation of infiltration opportunities lead to a reduction of this fee and thus provide targeted incentives for promoting stormwater infiltration.

Due to existing urban structures in the industrialized and highly sealed central area of Stuttgart-Feuerbach, the comprehensive implementation of the sponge city principle is only possible to a limited extent due to existing urban structures. Nevertheless, the sponge city concept is being pursued at various locations across the city and is intended to be applied especially in the new Rosenstein district on former railway areas. The findings from the pilot project in Feuerbach as well as those from the MAURICE project provide valuable approaches and practical recommendations for implementation.

Neckarpark – green spaces with infiltration basins

Municipal water management explicitly supports efforts to limit groundwater abstraction as a result of construction activities. Where groundwater abstraction is necessary in the context of building permits, alternative construction methods should be used where technically and economically feasible. Possibilities for rainwater infiltration should be checked.

Based on the available investigation results, the Contaminated Sites and Soil Protection Authority is also reviewing the hydraulic remediation measures carried out in the pilot area to assess their effectiveness and necessity.

Due to decades of intensive industrial use, soil contamination is present across nearly the entire pilot area. The infiltration of stormwater must therefore be critically assessed from the perspective of groundwater protection and, in particular, must not lead to the mobilization of existing contaminants. This key issue, which potentially conflicts with stormwater infiltration, will be investigated in greater depth over the coming years as part of the RAINBOW project (Interreg North-West Europe) in collaboration with the University of Stuttgart.

The continuous monitoring of groundwater levels will be continued in the pilot area beyond the project's lifetime. The findings from the MAURICE project prompted the water authority to establish a groundwater monitoring network in Stuttgart. Long-term observation and documentation of groundwater levels are necessary to assess the potential impacts of climate change on groundwater budget.

The effects of climate change are already clearly noticeable in Stuttgart. In particular, there has been a significant increase in the number of hot days, tropical nights, and heat waves in Stuttgart. Therefore, adapting to the consequences of climate change is of central importance and urgency. Stuttgart developed a climate adaptation concept as early as 2012. In the summer of 2024, it was decided to update the climate change adaptation plan. The measures described are to be consistently implemented by the various departments and responsible actors.

Since changes in precipitation patterns caused by climate change have a direct impact on the water cycle, irrigation, and drainage, the issue of water plays an important role in the climate change adaptation concept.

Many of the measures discussed as part of the MAURICE project—such as soil unsealing and infiltration—are also incorporated Stuttgart's climate change adaptation concept. Section 1 of the table below only provides a brief overview of the measures identified in field of action, related to water issues. The subsequent sections 2-5 in the table describe specific measures from the MAURICE Project that are under the responsibility of Environmental Department and can therefore be directly monitored and implemented.

Implemented actions		Roles	Timeframe	Finance & Resources		Monitoring	
title	description	Resp.	End date	manpower	Services & invest	Indicators	Resp.
1	**Climate Adaptation Concept Stuttgart (KLIMAX)** **e.g.** sustainable groundwater management irrigation management Blue-green infrastructure Precipitation fees (for rain runoff from sealed areas) road drainage (permeable surfaces) (rainwater management, tree trenches, sponge city concepts, potentials for unsealing)	Stuttgart municipal Administration	continously	The city's role	Depending on the measure		City of Stuttgart
2	Sustainable groundwater management / Infiltration	City of Stuttgart, Environmental Protection Department	ongoing measure, check whether infiltration is possible and proportionate	Sovereign task	Depending on the measure	l/s per year	PP3
3	Sustainable groundwater management / monitoring network	City of Stuttgart, Environmental Protection Department	ongoing measure, design and construction, evaluation of measure-ment series, correlation with climate data, calculations for future prognosis, and if applicable, derivation of recommendations for action	Sovereign task	Funding from the annual budget	Long-term data series	PP3

Implemented actions		Roles	Timeframe	Finance & Resources		Monitoring	
title	**description**	**Resp.**	**End date**	**manpower**	**Services & invest**	**Indicators**	**Resp.**
4	Sustainable groundwater management / Reduction of groundwater extractions	City of Stuttgart, Environmental Protection Department	ongoing measure	Sovereign task	Collect on a case by case basis	m^3/year reduction of groundwater discharge	PP3
5	Use of unsealing potentials, Update of surface sealing map Unsealing of courtyards (urban green)	City of Stuttgart, Environmental Protection Department	Surface sealing map, part areas until end of 2026	The city's role	Collect on a case by case basis Financing from yearly budget	Extract available, map will be further updated m^3 - unsealed area	City of Stuttgart

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MAURICE

Deliverable D.1.4.1
Action Plan Milan

Final version

05 2026

Contents

1. Introduction

The Metropolitan City of Milan lies within the Adda-Ticino groundwater basin of the Po Plain, an area characterized by extensive agricultural activity and a highly interconnected irrigation network. During the 2022 severe drought, the agricultural sector faced significant water shortages and reduced production, emphasizing the need for effective drought adaptation measures to prepare for an uncertain future climate. In line with MAURICE's "Sponge City" approach, our goal is to increase aquifer storage by enhancing infiltration through Agricultural Managed Aquifer Recharge (Ag-MAR), implemented via controlled off-season irrigation of agricultural fields.

Following the structure of the Regional Adaptation Support Tool developed by Climate-ADAPT, this document outlines the actions required to enable Ag-MAR adoption within the territory of the Est Ticino Villoresi Irrigation Consortium, which manages Ticino River water allocations for agricultural use east of Milan.

2. Preparing the ground for adaptation

Key Stakeholders for Ag-MAR

A Regional Implementation Group was established to coordinate Ag-MAR development in Lombardy (**Figure 1**). The core team included the Est Ticino Villoresi Irrigation Consortium (ETV), responsible for managing the canal network and coordinating with farmers; Politecnico di Milano, the University of Milan, and Softwater srl, which provided scientific and technical expertise for the experimental setup and data analysis; and the Lombardy Regional Government, whose involvement, through the General Directions for Water Resources and for Agriculture, was essential for assessing Ag-MAR integration into regional policies and planning instruments. Additional contributions came from the Metropolitan City of Milan, Metropolitana Milanese S.p.A., CAP Holding S.p.A., ISPRA, and territorial authorities such as Parco Agricolo Sud Milano and Parco del Fiume Ticino. In the final project phase, ANBI Lombardia, the Po River Basin Authority, and regional farmers' associations (Coldiretti and Confagricoltura) supported the assessment of Ag-MAR's suitability in Lombardy. At the center of the experimental phase was a group of farmers who implemented winter irrigation over two consecutive seasons.

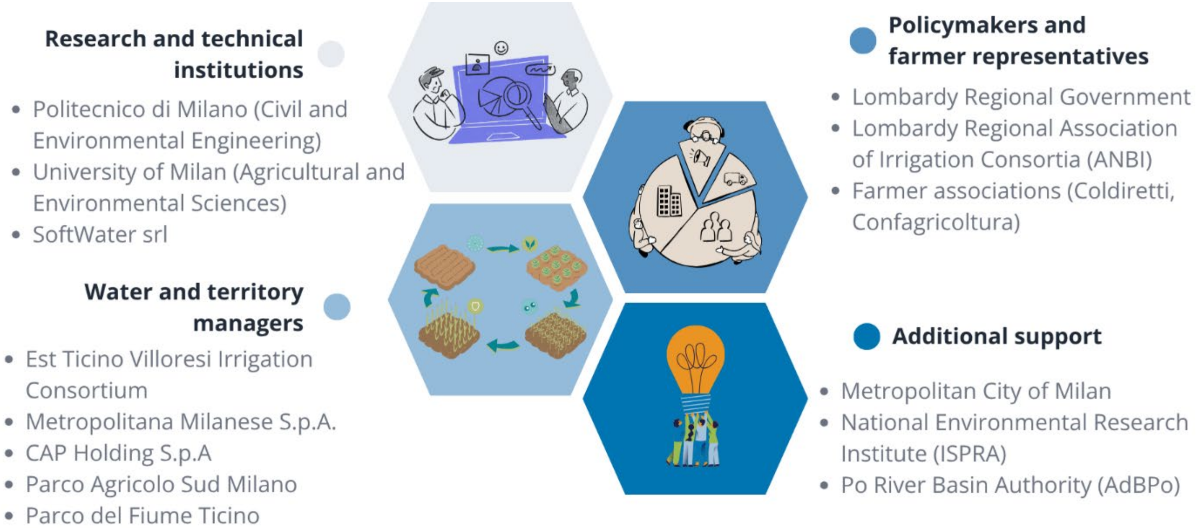


***Figure 1** – Stakeholders participating in Milan's Regional Implementation Group.*

Legal Obligations for Ag-MAR

Ag-MAR, as a form of managed aquifer recharge, is regulated in Italy by the Ministerial Decree 100/2016, which subjects these interventions to Environmental Impact Assessment procedures and defines technical and monitoring requirements to safeguard the quality of the water bodies involved. MAURICE has so far assessed only the quantitative effects of Ag-MAR. Further studies are needed to determine potential effects on water quality. However, to limit nitrate mobilization, Ag-MAR should be carried out before the fertilization season. Regarding water concessions in Lombardy, a portion of Ticino River water is already allocated to ETV for winter uses. Since Ag-MAR relies on the existing irrigation canal network and requires no dedicated infiltration infrastructure, the water use can still be classified under the existing “irrigation” concession type.

Communicating Ag-MAR

Our communication strategy with the local community pursued two main objectives: (i) raising awareness about regional groundwater resources, their connection to the irrigation system, and their vulnerability to climate change; and (ii) presenting our proposed adaptation measure. To achieve this, we engaged in local events and workshops and contributed to interviews and articles in the local press. The project’s final conference, where results were presented, served as a key moment for external communication, enabling the public and external administrations to understand the challenges, engage with the findings, and take interest in the proposed solution.

3. Assessing Climate Change Risks and Vulnerabilities

Conceptual model of the pilot area

The pilot area covered approximately 12 km x 26 km between the city of Milan and the Ticino River, including part of the territory managed by ETV. This area lies within the domain of the pre-existing Adda–Ticino groundwater model, which provided initial knowledge of its geological, hydrogeological, and hydrologic characteristics. Detailed investigations were carried out by Politecnico di Milano and the University of Milan to deepen the understanding of the system: A monitoring network of piezometers was installed, well abstraction data, irrigation, land use data and climate data were collected in collaboration with stakeholders. Additional efforts included extensive groundwater level measurement campaigns, the estimation of irrigation canals losses, lowland spring flowrate measurements, and infiltration tests in both dry irrigation canals and agricultural fields. All collected information was then used to construct the numerical model representing the aquifer system and its water balance components (**Figure 2**).

Numerical modelling for Ag-MAR evaluation

The pilot area was represented through two coupled numerical models: 1) the agro-hydrological model IDRAGRA (University of Milan), which performs a unit-based water balance integrating crop water requirements and irrigation practices and provides percolation estimates; and 2) the groundwater flow model developed by Politecnico di Milano using MODFLOW-USG to represent the aquifer over a two-year period starting in September 2023.

Climate models for future scenarios

Future climate scenarios for the pilot area were handled by SoftWater srl. Future climate variables were obtained by downscaling regional circulation models results (CNRM-ALADIN63, KNMI-RACMO22E, and ICTP-RegCM4-6) under the IPCC RCP 8.5 scenario. Two machine learning models (LSTM) were applied to simulate future dam-regulation practices. The net inflow to Lake Maggiore, future water availability in the Ticino River, and the diversion to the main irrigation canal managed by ETV were obtained for the period 2011–2050. Results indicate substantial interannual variability in aquifer percolation, but no projected conditions comparable to the 2022 drought within the next 25 years. However, because the 2022 event itself was not anticipated by climate projections, MAURICE included a replication of those extreme conditions in future simulations to stress-test the system.

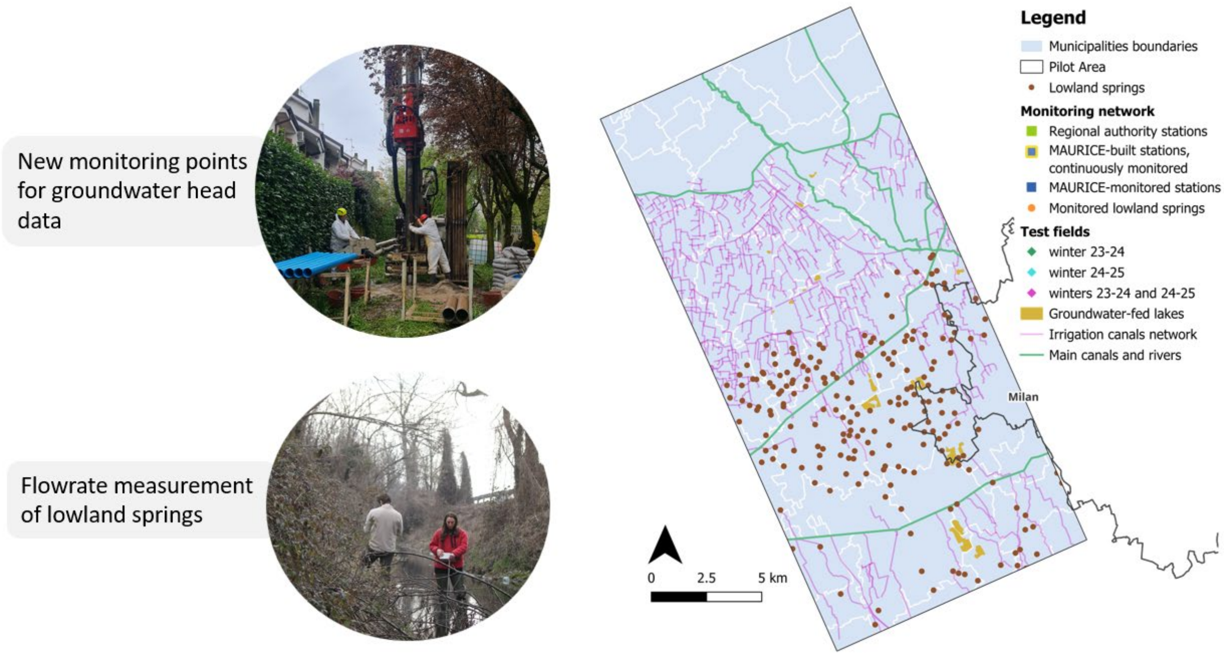


Figure 2 *– Data collection for development of conceptual and numerical models of the pilot area.*

4. Ag-MAR as the adaptation option

Ag-MAR consists of recharging aquifers in fall and winter by circulating water through the heritage irrigation canal network and allowing it to infiltrate agricultural fields and recharge the underlying aquifers. These aquifers then act as natural underground reservoirs, avoiding the costs and impacts of artificial reservoirs while providing benefits such as reduced evaporation, improved soil conditions, less frost damage, and greater canals efficiency in the following season. Ag-MAR is proposed as a low-cost adaptation measure, as it relies on existing irrigation infrastructure.

The measure can be adopted either as a mitigative strategy, restoring groundwater levels after droughts, or as a preventive strategy, building a buffer for irrigation during prolonged dry periods. Circulating water only within canals could be an alternative, but the network's configuration generally requires fields as infiltration areas, especially during rainfall events.

Scaling up Ag-MAR will require identifying the most suitable zones, prioritizing areas where similar practices have already shown positive results and territories vulnerable to drought. If Ag-MAR is integrated into a broader integrated water management approach, it should be paired with complementary interventions that can operate in synergy (**Figure 3**). Some planned activities already support this integration, such as water retention measures in Parco Agricolo Sud and the various flooding practices carried out in Parco del Ticino.

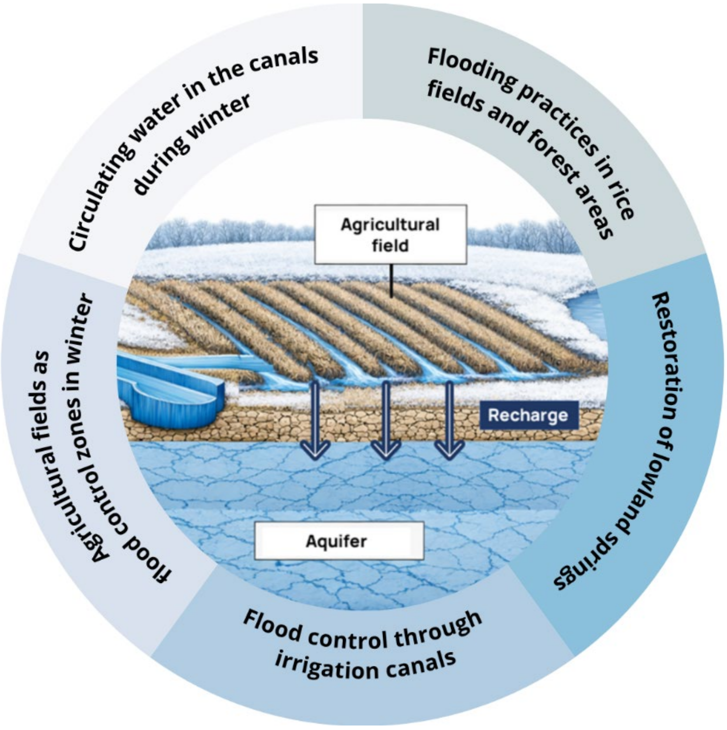


Figure 3 *– Synergies between Ag-MAR and environmental management activities in Lombardy facilitating an integrated water management framework.*

5. Criteria to assess Ag-MAR and similar drought adaptation options

A set of selection criteria was defined during the Regional Implementation Group meetings to evaluate Ag-MAR and other potential drought adaptation measures across vulnerable agricultural areas in Lombardy (**Table 1**). These criteria were assessed for Ag-MAR through two parallel lines of work: i) technical-operational, ii) management and policy.

The technical assessment was based on Ag-MAR tests carried out in the pilot area over three consecutive winters. These experiments involved three farmers, 33 hectares of test fields, and the mobilization of an average of 2.9 Mm^3/month of water with a 53% distribution efficiency. The total percolated volume during the Ag-MAR field tests as simulated by the numerical model was around 8 Mm^3 per year. The model also provided insights into optimal placement of infiltration fields relative to draining features such as lowland springs. Drought conditions were simulated to analyze the aquifer response to Ag-MAR applied before versus after an event, the latter facilitating faster recovery. Additional simulations tested the use of supplementary pumping wells to extract stored water during droughts, ensuring an equivalent flowrate to the deficit observed in 2022.

From a management perspective, several meetings were held with the Regional Implementation Group to identify the regulatory, social, economic and policy aspects involved in Ag-MAR, and to explore initial approaches for addressing them.

Table 1 – Selection criteria to assess aquifer-based drought adaptation options in Lombardy.

	Type	Selection criteria
	Efficiency	• Stored and available water • Reduced drought risk for crop production
	Economic sustainability	• Implementation, operation and maintenance costs
	Environmental impact	• Groundwater level response • Lowland springs benefiting from increased flow
	Social impact	• Stakeholders involved • Farmers involved
	Regulatory feasibility	• Consistency with the regional adaptation strategy and sectorial plans • Compliance with regional water and agriculture regulations

6. Implementing Ag-MAR

Ag-MAR implementation began during the project's lifetime through the activities described in the previous sections of the document and reported across the deliverables of the project. Positive pilot results, together with a clearer understanding of the current barriers to Ag-MAR adoption, have informed the definition of future activities for Ag-MAR uptake by the Est Ticino Villoresi Irrigation Consortium (**Table 2**).

Additional recommendations to facilitate Ag-MAR uptake based on the pilot experience include:

- **Farmer engagement survey**: Conduct a survey to assess farmers' interest and capacity to participate in winter-irrigation activities.
- **Cost-benefit assessment**: Carry out a cost-benefit analysis for both farmers and the irrigation consortium to inform the design of an incentive mechanism and a viable business model for regular or occasional Ag-MAR implementation across the consortium's territory.
- **Funding strategy**: Identify accessible funding mechanisms linked to sectoral planning instruments and stakeholders' programmed activities.
- **Operational alignment**: Coordinate planned canal maintenance activities with winter irrigation operations to ensure compatibility.
- **Rules for managing stored water**: Define clear operational rules for the use of stored water, for example, through the activation of well fields during drought emergencies.
- **Consortium-level database**: Develop a unified database covering the entire consortium area to support decision-making and data integration (groundwater levels, lowland springs, and well abstraction).
- **Identification of suitable infiltration zones**: Map priority areas for infiltration based on soil characteristics, crop types, and aquifer properties.
- **Integration into regional planning instruments**: Mainstream Ag-MAR into existing regional strategies and plans addressing drought risk (e.g., the Regional Strategy for Adaptation to Climate Change 2025, the Regional Sustainable Development Program 2023, the General Plan for Land Reclamation, Irrigation and Rural Area Protection 2023, and the Water Protection and Use Program 2016).

Table 2 - Programmed actions for Ag-MAR uptake by the Est Ticino Villoresi Irrigation Consortium.

	Measures		Roles		Timeframe		Finance & Resources
N	Title	Description	Resp.	Support	Start	End	
Action 1: Uptake and sharing MAURICE results							
1	Recommendations for Ag-MAR implementation	Develop and publish guidelines for Ag-MAR implementation on ETV and MAURICE websites.	Politecnico di Milano	ETV	March 2023	June 2026	MAURICE
2	Systematization and publication of collected data	Develop an online dashboard accessible to partners and the public, updated with groundwater, spring, canal, and climate data.	Politecnico di Milano	ETV, SoftWater srl, and University of Milan	May 2026	December 2026	MAURICE
3	Assessment of synergies with other entities and alignment with ongoing projects	Integrate Ag-MAR results into ETV internal processes and ongoing activities for related projects.	ETV	CNR-UNIPv-SUSPSI-CANTON TICINo	2025	2028	MAURICE-WINCA4TI
Action 2: Promotion of Ag-MAR through winter irrigation of agricultural fields							
4	Promoting winter irrigation in standard agricultural practices	Organize local meetings to engage farmers and agricultural associations	ETV	Agricultural associations and farmers	March 2023	2029	ETV-MAURICE
5	Revision of ETV policy to promote winter irrigation	Assess the reduction of water tariff for winter irrigation purposes	ETV		2024	2030	ETV
Action 3: Increase the knowledge of the water distribution system							
6	Monitoring of the water circulation system	Conduct monitoring campaigns of diverted flows during both summer and winter.	ETV	Politecnico di Milano	March 2023	2030 (indicative)	ETV-MAURICE
7	Automation of the distribution system	Implement an integrated system of gates equipped with automated measurement devices.	ETV		April 2026	2030 (indicative)	PNRR

7. Recommended Monitoring and Evaluation Framework

Once Ag-MAR becomes an ordinary practice within an irrigation consortium, the monitoring and evaluation framework should be structured around three core activities:

- **Integrated data management**: Collect, process, and share data within a unified database accessible to water and land management authorities. The monitoring system should be progressively expanded to include lowland-spring observations and irrigation-well abstraction data.
- **Periodic performance reviews**: Hold regular meetings to review a set of monitoring parameters and indicators (**Table 3**) and assess the effectiveness of Ag-MAR operations, adjusting the operational strategy when needed.

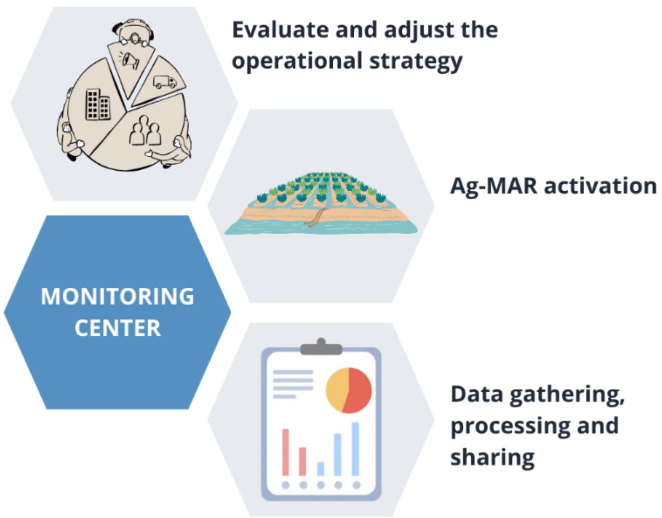


Figure 4 *- Key activities of the Ag-MAR monitoring center.*

- **Enable Ag-MAR activation:** Oversee piezometric trends and determine when Ag-MAR should be activated in response to critical groundwater depletion thresholds.

Building on these components, a dedicated monitoring centre can be established (**Figure 4**).

Table 3 *- Proposed set of monitoring parameters and effectiveness indicators for the implementation of Ag-MAR*

Monitoring parameters	Groundwater level
	Hectares of irrigated agricultural land in the period November-February
	Kilometres of irrigation canals that carry water year-round
	Volume of infiltrated water
	Volume of water distributed to the fields
	Groundwater and Ticino River quality*
Ag-MAR effectiveness indicators	% of water actually stored and available for consumption
	% of demand met
	% of summer irrigation demand met
	Number of stakeholders and farmers involved
	Number of lowland springs benefiting from increased flow

(*) Quality parameters should also be included to account for nitrate mobilization and ensure that infiltration activities do not compromise aquifer quality.

MAURICE

Action Plan for Jaworzno

Version final

05 2026

Contents

1. Introduction

The document presents the planned actions of the City of Jaworzno aimed at strengthening climate change adaptation and increasing urban resilience in areas affected by geohazards related to historical mining activities. Building on the results of the MAURICE project, the proposed measures focus on integrating blue-green infrastructure (BGI) solutions into investment planning, strategic decision-making, stakeholder engagement, and educational activities.

The actions are designed to support the implementation of the sponge city approach, improve sustainable rainwater management, and enhance awareness of climate-related risks and adaptation opportunities. Together, they contribute to a more resilient, sustainable, and climate-adaptive urban environment while addressing the specific challenges associated with post-mining areas.

The document was developed project by the Lead Partner of the MAURICE, the Central Mining Institute – National Research Institute (LP1), in close cooperation with the Project Partner, the City of Jaworzno (PP2).

Image created by MAURICE with AI

2. Planned actions in the City of Jaworzno

Action 1: Establishment of a Municipal Advisory Team for Investment Review in Geohazard Areas

A dedicated *Municipal Advisory Team for Investment Review in Geohazard Areas* will be established within the Municipality of Jaworzno. The Team's responsibilities include reviewing and providing opinions on planned investments, with particular focus on areas exposed to geological risks resulting from historical mining activities. The Team will support the implementation of the sponge city approach and climate change adaptation by promoting the use of blue-green infrastructure (BGI) solutions. The Team will use the BGI Guidelines and the interactive BGI catalogue developed within the MAURICE project as supporting tools for assessing appropriate rainwater management solutions.

Objective

To ensure that investment processes in geohazard areas support climate change adaptation and include appropriate blue-green infrastructure solutions, while taking into account geological, mining and water conditions.

Timeframe

By June 2026

Expected results

- Structuring the investment planning mechanism
- increased use of BGI solutions in investment processes
- improved resilience of urban areas to climate change
- reduced environmental and geological risks

Responsible Partner:

- PP2 Jaworzno

Image created by MAURICE with AI

Action 2: Adoption of the regulation of the Mayor of Jaworzno and integration of BGI tools

The Mayor of Jaworzno is in process of developing a regulation specifying the principles of operation of the Municipal Advisory Team *for the Investment Review in Geohazard Areas*, which will be adopted as a regulation of the Mayor of Jaworzno. The regulation will also introduce the results of the MAURICE project, including the BGI Guidelines and the interactive BGI catalogue, into the work of the Team. The regulation of the Mayor of Jaworzno will serve as a formal mechanism supporting the implementation of the sponge city approach and climate change adaptation in Jaworzno. Quarterly reporting on the Team's activities to the responsible Deputy Mayor will be introduced, including periodic reports summarising investment reviews and recommendations.

Objective

To establish a formal framework for integrating BGI solutions into municipal decision-making processes, supporting climate change adaptation.

Timeframe

- Adoption of the regulation of the Mayor of Jaworzno - by June 2026
- Reporting on the Team's activities – quarterly, starting from September 2026

Expected results

- formal implementation of MAURICE project outputs at the municipal level
- improved quality and consistency of investment assessment in geohazard areas
- increased use of BGI solutions in investment processes
- improved monitoring and transparency of the Team's activities through quarterly reporting

Responsible Partner:

- PP2 Jaworzno

Image created by MAURICE with AI

Action 3: Investor pathway leaflet development

A structured investor pathway will be developed to guide private investors in implementing blue-green infrastructure (BGI) solutions, particularly in geohazard areas. The pathway will include step-by-step guidance on investment preparation, required geological and hydrological analyses, and the selection of appropriate BGI solutions using the BGI Guidelines and the interactive catalogue developed within the MAURICE project. The pathway will be presented in the form of a leaflet and promoted during project events, including the final conference and workshops.

Timeframe
By June 2026

Objective
To support investors in implementing BGI solutions and ensuring safe and climate-resilient investments.

Expected results

- increased use of BGI solutions in private investments
- improved awareness of geological risks among investors
- better quality of investment planning in geohazard areas

Responsible Partners

- PP2 Jaworzno (structure, administrative pathways, editing and printing)
- LP GIG-PIB (part of content related to BGI technologies selection)

Image created by MAURICE with AI

Action 4: Educational activities on BGI and climate change adaptation

Educational activities foreseen in the Climate Adaptation Plan for Jaworzno will be implemented in the form of workshops and stakeholder engagement initiatives. Two workshops will be organised to increase awareness of climate change adaptation and blue-green infrastructure (BGI) solutions among residents, investors and local stakeholders. The workshops will promote sustainable rainwater management and the sponge city approach, using the BGI Guidelines and the interactive BGI catalogue developed within the MAURICE project. They will also address local conditions, including geological risks related to post-mining areas. Educational activities may also be carried out at the GeoSfera Ecological and Geological Education Centre, where practical examples of BGI solutions are presented.

Timeframe
Workshop 1 – by December 2026
Workshop 2 – by June 2027

Objective
To strengthen knowledge and acceptance of BGI solutions and the sponge city approach among local stakeholders.

Expected results

- implementation of educational measures defined in the Climate Adaptation Plan
- increased awareness of blue-green infrastructure (BGI) solutions and climate change adaptation among residents and stakeholders
- increased interest in applying BGI solutions in practice

Responsible Partners

- PP2 Jaworzno: organisation
- LP GIG-PIB: content

Image created by MAURICE with AI

Action 5: Update of the Climate Adaptation Plan for Jaworzno

The Municipal Advisory Team for Investment Review in Geohazard Areas will be involved in the update of the Climate Adaptation Plan for Jaworzno. The team will contribute to the identification and assessment of climate-related risks, with particular focus on geohazards resulting from historical mining activities, including discontinuous ground deformations. The updated Climate Adaptation Plan will include dedicated activities on climate education and awareness raising on blue-green infrastructure (BGI) solutions as one of its key measures, using the results of the MAURICE project, including the BGI Guidelines and the interactive BGI catalogue. This action will support the integration of geohazard considerations and BGI solutions into strategic planning in Jaworzno.

Objective
To strengthen the Climate Adaptation Plan for Jaworzno by incorporating geohazard risks and BGI solutions.

Timeframe
By June 2027

Expected results

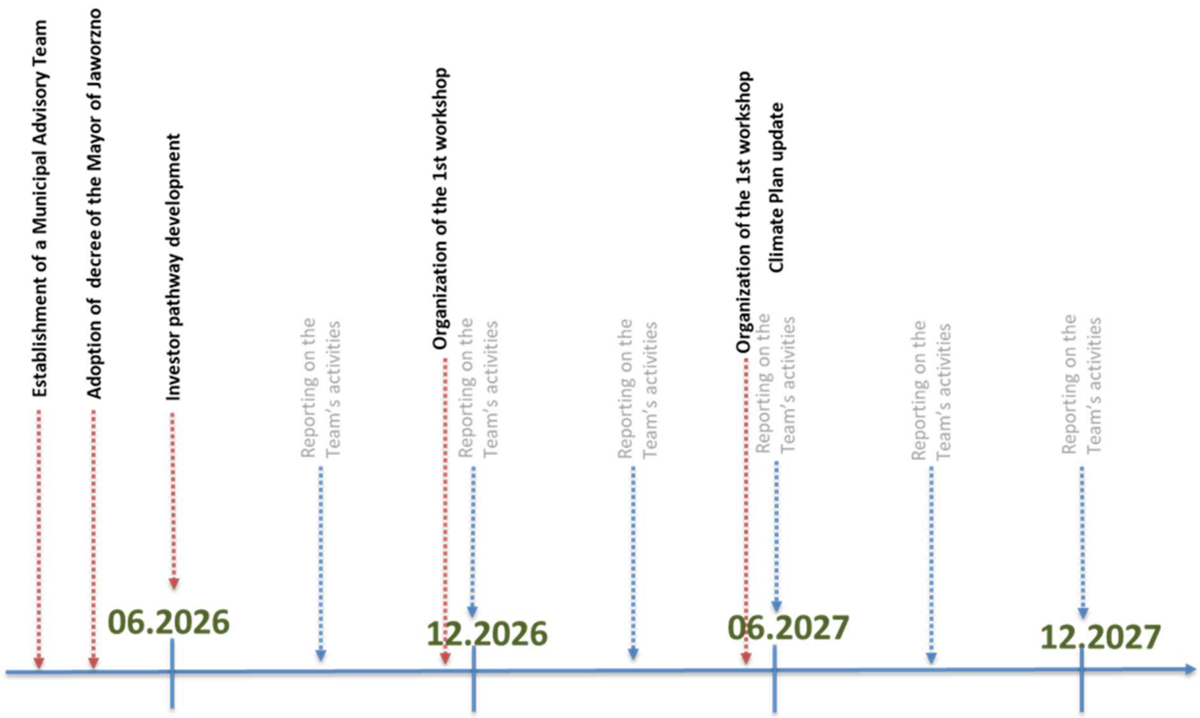
- better integration of climate change adaptation and spatial planning activities
- increased resilience to climate change
- reduced risk in vulnerable areas

Responsible Partner:

- PP2 Jaworzno

Image created by MAURICE with AI

3. Action Plan Timeline



4. Summary

In conclusion, the planned actions will ensure the long-term implementation and sustainability of the MAURICE project results in the City of Jaworzno. By integrating blue-green infrastructure solutions into investment planning, strategic documents, and stakeholder engagement processes, the city will strengthen its capacity to adapt to climate change and address geohazards related to historical mining activities. The cooperation between the Central Mining Institute – National Research Institute and the City of Jaworzno provides a strong foundation for the effective transfer of knowledge and practical implementation of innovative solutions. Together, these measures will contribute to creating a safer, more resilient, and environmentally sustainable urban environment for current and future generations.

Deliverable D.1.4.1

Action plan Novy Bydzov

Final Version

05 2026

Table of content

1. Introduction

The MAURICE project enabled the city of Novy Bydzov to initiate adaptation measures to mitigate the impacts of climate change on the city's water management. The activities connected with the Pilot Action Novy Bydzov specified:

- risks of climate change impacts on the city's water management,
- measures to eliminate these impacts.

The rising price and potential shortage of drinking water and damage to surface waters due to the discharge of rainwater through the unified sewage system through relief channels into the Cidlina River (without treatment) were assessed as significant risks related to climate change. Therefore, the city is interested in examining the possibilities of implementing effective rainwater management, including the possibility of replacing drinking water with rainwater for technological purposes.

To implement rainwater management in the city of Novy Bydzov, an action plan was developed with the help of the MAURICE project, the characteristics and individual objectives of which are described in the next section.

2. Adaptation measures

The action plan for the implementation of functional rainwater management consists of 5 basic adaptation measures, which were developed by the MAURICE project team and adopted by the management of the city of Novy Bydzov for the next period. Part of the adaptation measures has already been fulfilled during the implementation of the MAURICE project (Actions No. 1 to No.3), Actions No.4 and No.5 are planned for the period after the end of the MAURICE project.
For each adaptation measure, the main objective expected from the implementation of the measure is stated, as well as the sub-tasks for implementing the measure. The responsible persons and departments of the municipal office responsible for the implementation of the tasks are defined. A very important part of the implementation of the measure are the assumptions, means and conditions enabling implementation, as well as the financial plan and the timetable for their implementation. An integral part of the action plan is the monitoring of the implementation of the action plan and the evaluation of how the objectives have been met. The action plan states which persons and departments of the municipal office are responsible for monitoring the progress of the implementation of the tasks and how the monitoring should take place over time.

2.1. Action No. 1 - Creation of a regional implementation group (RIG) for the implementation and coordination of rainwater management and definition of its area of activity

- *Main goal:* to create a group consisting of experts and representatives of the local government and the city state administration for the implementation of rainwater management in Novy Bydzov
- *Subtasks:*
    - Creation of a group consisting of experts and representatives of the city's local government and state administration

- Creating a professional foundation in the issue Rainwater Management
- increasing awareness of the issue among representatives of local government and state administration - education
- Supervision of the implementation of measures

❖ *Responsibility for completing the task:* MAURICE project team, RIG, Commission for the Environment, Renewable Resources and Waste Management of the City Council (CERRWM), Environmental Department of NB

❖ *Prerequisites, means and conditions enabling implementation:*

- MAURICE project team, expert representatives – PhotonWaterTechnology Ltd., Czech Water Association , representatives of the Environmental Department, the Commission for the Environment, Renewable Resources and Waste Management of the City Council, representatives of the Technical Services of the City of Novy Bydzov
- Concentration of professional studies, methodological guidelines and existing support subsidy titles for RWM projects - Environmental Department of NB
- Education of representatives of local government and state administration – seminars, conferences, excursions on the given issue
- Regular evaluation of the progress of implementing rainwater management

❖ *Financial plan:*

- Use of support from the MAURICE project – 04/2023 – 06/2026
- Support from the city budget

❖ *Timetable:*

- Establishment of a regional implementation group – 12/2023
- Professional studies, methodological guidelines and existing support grant titles - 1st stage - current knowledge as of 2023 - 03/2024, and subsequently continuous updating
- Education – organizing educational events, enabling participation in educational events – at least once a year for selected RIG members and administrators of NB

❖ *Monitoring and evaluation:*

- Regional Implementation Group (RIG), Commission for the Environment, Renewable Resources and Waste Management of the City Council (CERRWM)- coordination meetings - 2 times a year

Figure No.1: Meeting of Regional Implementation Group in December 2023

2.2. Action No. 2 – Preparation of a water management study to assess the prospects for rainwater management

- *Main objective:* assessment of the impacts of climate change on water resources (groundwater, drinking water, process water, surface water) and proposal of measures to increase the resilience of the city's water management to the impacts of climate change

- *Subtasks:*

    - Assessment of natural conditions and climatic situation in Novy Bydzov , their expected development including climate change,
    - Description of the types and balance of water (sources and consumption) in Novy Bydzov and their resilience to the impacts of climate change
    - Proposal for measures to increase the resilience of the city's water management system to the impacts of climate change
    - Designing an optimal strategy for implementing rainwater management in Novy Bydzov
    - Identifying suitable locations and buildings owned by the city for the implementation of effective rainwater management,

- *Responsibility for completing the task:*

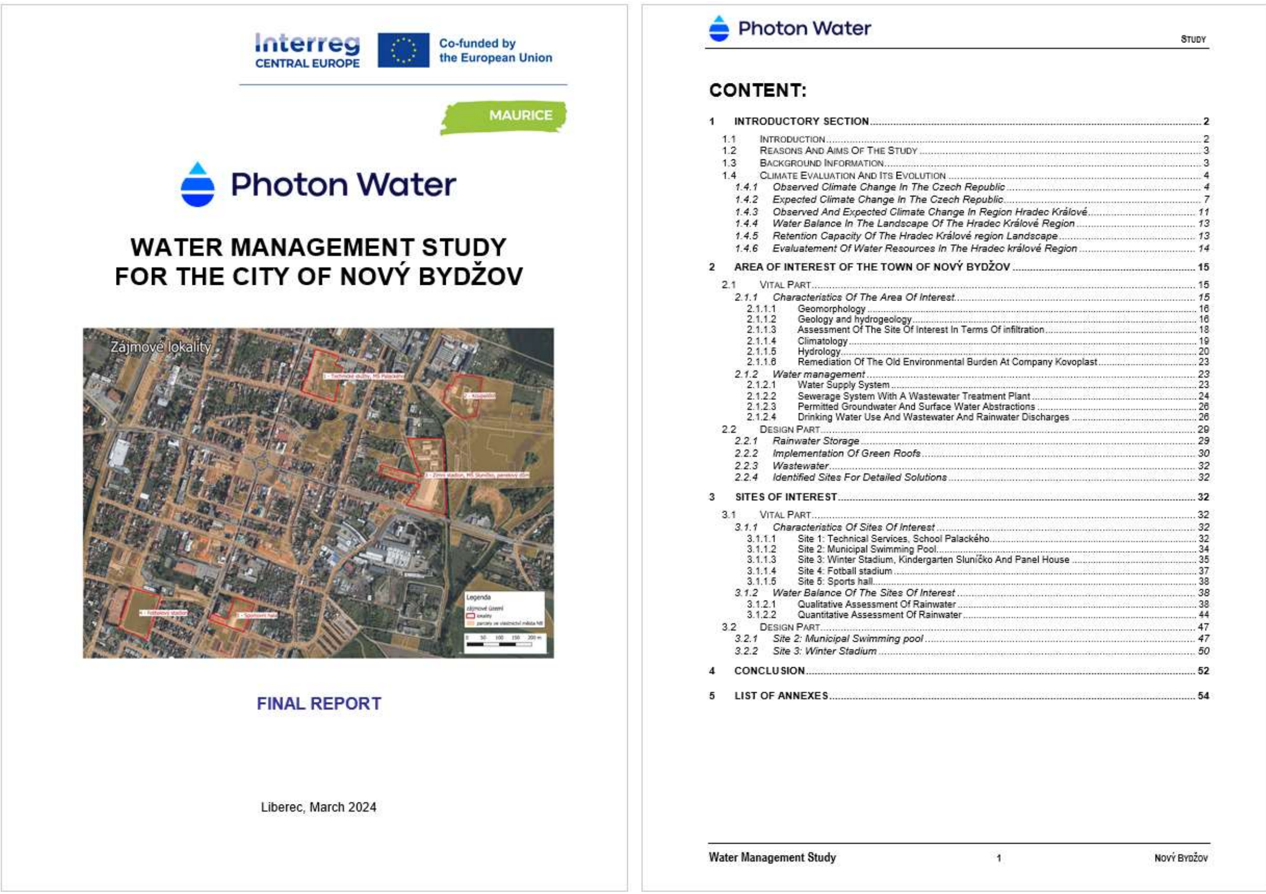
    - Development of the assignment: MAURICE project team
    - Processors: specialized consulting company in the field of water management
    - Regional Implementation Group: consultations and expert and policy comments
    - City management: approval of water management study

- *Timetable:*

    - Preparation of project documentation for public procurement – 06/2023
    - End of the selection process - 08/2023
    - Study submission - 03/2024
    - Study acceptance – 06/2024

- *Monitoring and evaluation:*

    - MAURICE project, Regional implementation group – coordination meetings and peer review
    - City Council – adoption of the study



Interreg CENTRAL EUROPE — Co-funded by the European Union

MAURICE

Photon Water

WATER MANAGEMENT STUDY
FOR THE CITY OF NOVÝ BYDŽOV

Zájmové lokality

FINAL REPORT

Liberec, March 2024

Photon Water — STUDY

CONTENT:

Water Management Study 1 Nový Bydžov

Figure No.2: The title page and content of the Water Management Study for the Novy Bydzov

2.3. Action No.3 - Preparation of complete project technical documentation with the application of measures for the use of rainwater and the reduction of drinking water consumption in selected facilities owned by the city of Novy Bydzov with the issuance of a building permit for their implementation

- *Main objective:* creating technical conditions for reducing drinking water consumption at the city swimming pool and the ice rink – facilities owned by the city

- *Subtasks:*

  - Development of project documentation "Novy Bydzov - water management in the swimming pool area",
  - Development of project documentation "Novy Bydzov - water management in the winter stadium area"
  - Securing decisions, opinions, statements of the relevant state administration bodies, statements of owners and administrators of infrastructure,
  - Securing a building permit

- *Responsibility for completing the task:*

  - Development of the assignment: MAURICE project team

- Processors: specialized consulting company in the field of water management
- Regional Implementation Group: consultations and expert and policy comments
- Department of Construction and Environment: approval of project documentation

❖ *Timetable:*

- Development of project documentation for public procurement – 04/2024
- End of the selection process – 06/2024
- Submission of project documentation – 03/2025
- Obtaining opinions on construction projects from responsible authorities – 07/2025
- Building permit for constructions – 09/2025

❖ *Monitoring and evaluation:*

- MAURICE project team, Regional Implementation Group – coordination meetings and peer review
- Construction and Environment Department – supervision of the completeness of technical project documentation, issuance of building permits

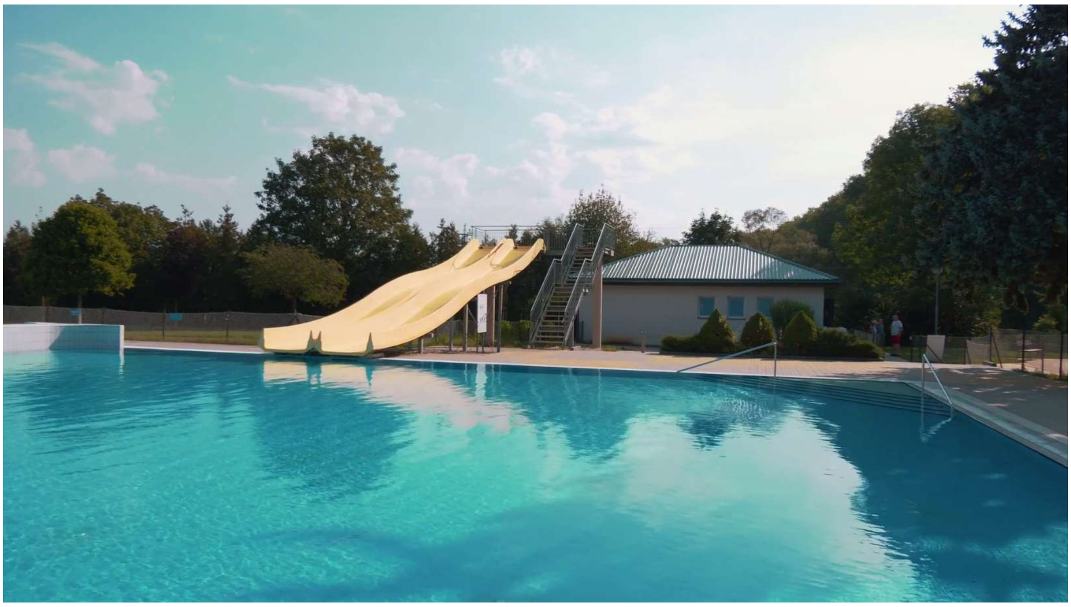


Figure No.3: Pilot test of swimming pool water purification technology

Městský úřad Nový Bydžov
Odbor výstavby a životního prostředí
Masarykovo náměstí 1, 504 01 Nový Bydžov

STAVEBNÍK: Město Nový Bydžov, IČ 00269247, Masarykovo náměstí č. p. 1, 504 01 Nový Bydžov zastoupeno: Photon Water Technology s. r. o., IČ 04568095, Generála Svobody č. p. 25/108, Liberec XII-Staré Pavlovice, 460 01 Liberec 1

VÁŠ DOPIS ZN.:
ZE DNE: 16.07.2025
ČÍSLO JEDNACÍ: NB-V/22547/2025/Lon
SPIS. ZNAČKA: 3406/2025
ID ZÁMĚRU: Z/2025/132231

Datum	Oprávněná úřední osoba	E-mail	Telefon
28.08.2025	Ing. Eva Lonská	lonska@novybydzov.cz	495 703 967

Rozhodnutí

Výroková část

Městský úřad Nový Bydžov, odbor výstavby a životního prostředí, jako věcně příslušný stavební úřad (dále jen stavební úřad), podle ustanovení § 30 odst. 1 písm. f) a odst. 3 písm. a) zákona č. 283/2021Sb., stavební zákon, ve znění pozdějších předpisů (dále jen stavební zákon), jako místně příslušný správní úřad podle ustanovení § 11 odst. 1 písm. b) zákona č. 500/2004Sb., správní řád, v platném znění (dále jen správní řád), v souladu s ustanovením § 334/b stavebního zákona a v souladu s ustanovením § 115 odst. 1 zákona č. 254/2001 Sb., zákon o vodách a o změně některých zákonů (vodní zákon), v řízení přezkoumal podle § 184 až 198 stavebního zákona, žádost o povolení záměru ze dne 16.07.2025, kterou podalo Město Nový Bydžov, IČ 00269247, Masarykovo náměstí č. p. 1, 504 01 Nový Bydžov, prostřednictvím svého zmocněnce: Photon Water Technology s. r. o., IČ 04568095, Generála Svobody č. p. 25/108, Liberec XII-Staré Pavlovice, 460 01 Liberec 1 (dále jen stavebník), a na základě provedeného řízení:

I. Vydává podle § 197 stavebního zákona povolení záměru: Projektová dokumentace Nový Bydžov - hospodaření s vodou v areálu koupaliště na pozemcích: pozemková parcela číslo 1128/3, stavební parcela číslo 3098 v katastrálním území: Nový Bydžov (dále jen záměr).

Záměr obsahuje:
SO 01 - Stavební část
PS 01 - Strojně-technologická část
PS 02 - Strojní elektroinstalace a MaR
Stávající dešťové vody budou nově zaústěny do akumulační nádrže dešťových vod AND. Dešťové vody budou využívány pro závlahu areálu koupaliště nebo jako vstupní voda na nově navrženou

Městský úřad Nový Bydžov
Odbor výstavby a životního prostředí
Masarykovo náměstí 1, 504 01 Nový Bydžov

STAVEBNÍK: Město Nový Bydžov, IČO 00269247, Masarykovo náměstí č. p. 1, 504 01 Nový Bydžov zastoupeno: Photon Water Technology s. r. o., IČO 04568095, Generála Svobody č. p. 25/108, Liberec XII-Staré Pavlovice, 460 01 Liberec 1

VÁŠ DOPIS ZN.:
ZE DNE: 16.07.2025
ČÍSLO JEDNACÍ: NB-V/24322/2025/Lon
SPIS. ZNAČKA: 3406/2025
ID ZÁMĚRU: Z/2025/132231

Datum	Oprávněná úřední osoba	E-mail	Telefon
17.09.2025	Ing. Eva Lonská	lonska@novybydzov.cz	495 703 967

Sdělení o nabytí právní moci

Městský úřad Nový Bydžov, odbor výstavby a životního prostředí, jako stavební úřad, věcně příslušný dle ustanovení § 30 odst. 1 písm. f) a odst. 3 písm. a) zákona č. 283/2021Sb., stavební zákon, ve znění pozdějších předpisů, v souladu s ustanovením § 73 až § 75 zákona č. 500/2004 Sb., správní řád, v platném znění, vám sděluje, že rozhodnutí ze dne 28.08.2025 vydané pod č.j.: NB-V/22547/2025/Lon, na záměr: Projektová dokumentace Nový Bydžov - hospodaření s vodou v areálu koupaliště, na pozemcích: pozemková parcela číslo 1128/3, stavební parcela číslo 3098 v katastrálním území: Nový Bydžov,

nabylo právní moci dne 17.09.2025
a je vykonatelné.

Ing. Jan Rejthárek
vedoucí odboru

Příloha:
Štítek „STAVBA POVOLENA"

Rozdělovník:
Datová schránka:
Photon Water Technology s. r. o., Generála Svobody č. p. 25/108, Liberec XII-Staré Pavlovice, 460 01 Liberec 1, DS: PO, 7txb8ed

Digitálně podepsal Ing. Jan Rejthárek
Datum: 19.09.2025 07:33:22 +02:00

Figure No.4: Approval of documentation by the relevant authorities and obtaining a building permit

2.4. Action No.4 – Implementation of constructions with the application of measures for the use of rainwater and the reduction of drinking water consumption in selected facilities owned by the city of Novy Bydzov

- *Main objective:* to build structures to reduce drinking water consumption - building a pool water treatment plant at the Municipal Swimming Pool, building a rainwater collection system, a rainwater and groundwater treatment plant for the production of technological water for ice production for the winter ice rink at the Winter Stadium.

- *Subtasks:*
  - Implementation of a construction project to reduce drinking water consumption – construction of a swimming pool water treatment plant at the Municipal Swimming Pool,
  - Implementation of a construction to reduce drinking water consumption – construction of a rainwater collection system, a rainwater and groundwater treatment plant for the production of technological water for ice production for the winter ice rink at the Winter Stadium.
- *Responsibility for completing the task:* Department of Investment and Development of the City of Novy Bydzov

- ***Prerequisites, means and conditions enabling implementation:***
  - Approved project documentation with a valid building permit
  - Subsidy titles supporting the implementation of measures to limit the impacts of climate change
- ***Financial plan: required investment:***
  - City swimming pool: 5,900,000 CZK - 236,000 €
  - Winter stadium: 6,500,000 CZK - 260,000 €
  - Use of subsidy titles of the Czech Republic
- ***Timetable :***
  - Implementation is tied to the use of subsidy titles supporting the implementation of measures to limit the impacts of climate change –
  - Expected implementation by 2030

- *Monitoring and evaluation:* regional implementation group, Commission for the Environment, Renewable Resources and Waste Management of the City Council (CERRWM), City Council - check 1 time per year

Figure No.5: Winter Stadium Building

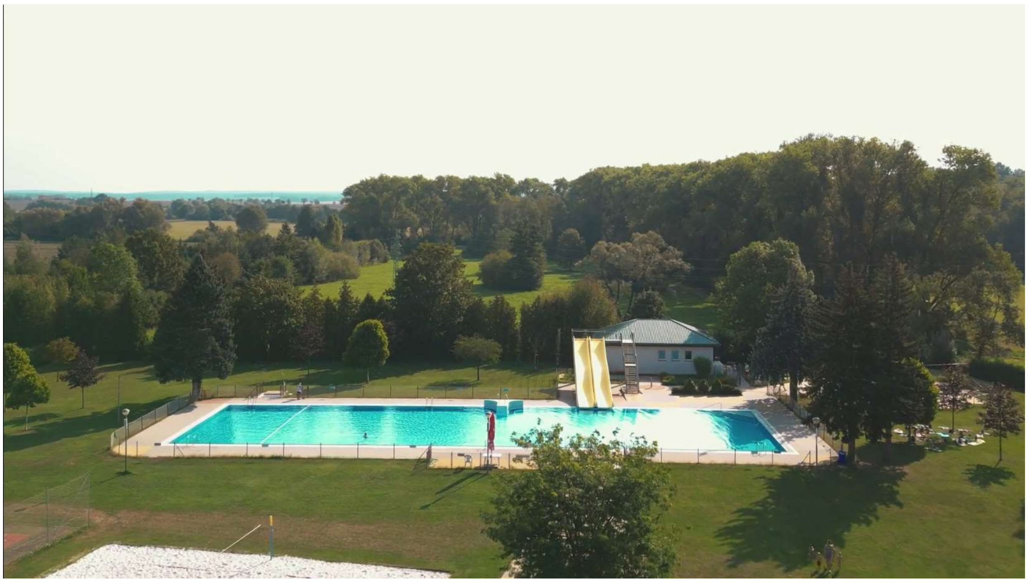


Figure No.6: Municipal swimming pool area

2.5. Action No. 5 - Applying requirements for the implementation of rainwater management for new buildings and renovations as part of building permits in Novy Bydzov

- *Main objective:* applying the principle of using rainwater on the builder's land in new construction and in the reconstruction of buildings.
- *Means and conditions enabling implementation:*
  - Methodological guidelines developed and made available by the MAURICE project
  - Legislative environment of the Czech Republic and the EU
- *Responsibility for completing the task:* Department of Construction and Environment of NB
- *Financial plan:*
  - to make maximum use of subsidy titles of the Czech Republic for buildings owned by the city
  - for private projects: costs covered by the investor
- *Timetable:*
  - immediately
- *Monitoring and evaluation:*
  - Environmental department, sewerage system operator when approving the project documentation of the construction - each construction
  - Regional Implementation Group, Commission for the Environment, Renewable Resources and Waste Management of the City Council (CERRWM), City Council - inspection 1 time per year

Summary of the action plan of the city of Novy Bydzov in implementing effective rainwater management

Measures		Roles		Timeframe		Finance & Resources	Monitoring	
title	**description**	**Resp.**	**implement**	**start**	**end**		**Indicators**	**Resp.**
Action No. 1 – Creation of a regional implementation group for the implementation and coordination of rainwater management and definition of its area of activity								
1.1 Creation of Regional Implementation Group	creation of a group consisting of experts and representatives of the city's local government and state administration	MAURICE project team	identify the members of RIG RIG formation	04/2023	12/2023	MAURICE	RIG formation	MAURICE project team
1.2 Creating a professional foundation in the issue Rainwater Management	concentration of professional studies, methodological guidelines and existing support subsidy titles for RWM projects	MAURICE project team	identification of professional studies, methodological guidelines and existing support subsidy titles for RWM projects	06/2023	03/2023	MAURICE	Creating a professional foundation in the issue Rainwater Management	MAURICE project team
		Environmental Department of NB	database management and identification of professional studies, methodological guidelines and existing support subsidy titles for RWM projects	04/2023	consistently	city budget		Environmental Department of NB
1.3 Increasing awareness of the issue among representatives of local government and state administration	education of representatives of local government and state administration – seminars, conferences, excursions on the RWM	MAURICE project team	identification of educational means for RWM projects	06/2023	06/2026	MAURICE	Participation of selected staff on education at minumum once for your	RIG - up to the end of project MAURICE CERRWM - after project MAURICE
		Environmental Department of NB	identification of educational means for RWM projects identification of participants on education		consistently	city budget		
1.4 Supervision of the implementation of RWM measures	regular evaluation of the progress of implementing rainwater management	MAURICE project team	supervision of the implementation of RWM measures	06/2023	06/2026	MAURICE	number of RWM measures per year	RIG - up to the end of project MAURICE CERRWM - after project MAURICE
		Environmental Department of NB		06/2026	consistently	city budget		
Action No. 2 – Preparation of a water management study to assess the prospects for rainwater management								
2. Water Management Study	assessment of the impacts of climate change on water resources and proposal of measures to increase the resilience of the city's water management to the impacts of CC	MAURICE project team	development of the assignment consultations and expert and policy comments	04/2023 08/2023	06/2026 03/2024	MAURICE	Study submission	MAURICE project team
		winner of the tender	processing of study	08/2023	03/2024			
		RIG	consultations and expert and policy comments	08/2023	06/2024		Study acceptance	City Council
		City Council	approval of water management study	04/2024	06/2024			

Summary of the action plan of the city of Novy Bydzov in implementing effective rainwater management

Measures		Roles		Timeframe		Finance & Resources	Monitoring	
title	**description**	**Resp.**	**implement**	**start**	**end**		**Indicators**	**Resp.**
Action No.3 – Preparation of complete project technical documentation with the application of measures for the use of rainwater and the reduction of drinking water consumption in selected facilities								
3.1 Development of project documentation "Novy Bydzov - water management in the swimming pool area"	complete project technical documentation with the issuance of a building permit for their implementation	MAURICE project team	development of the assignment consultations and expert and policy comments	02/2024	04/2024	MAURICE	Project documentation submission	MAURICE project team
		winner of the tender	processing of study	06/2024	03/2025			
		RIG	consultations and expert and policy comments	06/2024	03/2025		Project documentation acceptance, buidling permits	Department of Construction and Environment of NB
		Department of Construction and Environment of NB	checking the completeness of project documentation issuance of building permits	06/2025	09/2025			
3.2 Development of project documentation "Novy Bydzov - water management in the winter stadium area"	complete project technical documentation with the issuance of a building permit for their implementation	MAURICE project team	development of the assignment consultations and expert and policy comments	02/2024	04/2024	MAURICE	Project documentation submission	MAURICE project team
		winner of the tender	processing of study	06/2024	03/2025			
		RIG	consultations and expert and policy comments	06/2024	03/2025		Project documentation acceptance, buidling permits	Department of Construction and Environment of NB
		Department of Construction and Environment of NB	checking the completeness of project documentation issuance of building permits	06/2025	09/2025			
Action No.4 – Implementation of constructions with the application of measures for the use of rainwater and the reduction of drinking water consumption in selected facilities owned by the city of Novy Bydzov								
4.1 Implementation of a construction project to reduce drinking water consumption – construction of a swimming pool water treatment plant at the Municipal Swimming Pool	to build structures to reduce drinking water consumption - building a pool water treatment plant at the Municipal Swimming Pool	Department of Investment and Development of NB	identification of an appropriate subsidy titles for project investment	01/2026	12/2030	236 000,00 €	identification of an appropriate subsidy titles for project investment - check 1 time per year	Department of Investment and Development of NB CERRWM
			public tender for a contractor				public tender for a contractor	Department of Investment and Development of NB CERRWM
			supervision of construction implementation				supervision of construction implementation	Department of Investment and Development of NB CERRWM
							construction implementation	CERRWM

Summary of the action plan of the city of Novy Bydzov in implementing effective rainwater management

Measures		Roles		Timeframe		Finance & Resources		Monitoring	
title	**description**	**Resp.**	**implement**	**start**	**end**			**Indicators**	**Resp.**
Action No.4 – Implementation of constructions with the application of measures for the use of rainwater and the reduction of drinking water consumption in selected facilities owned by the city of Novy Bydzov									
4.2 Implementation of a construction project to reduce drinking water consumption – construction of a swimming pool water treatment plant at the Winter Stadium	to build structures to reduce drinking water consumption - building a pool water treatment plant at the Municipal Swimming Pool	Department of Investment and Development of NB	identification of an appropriate subsidy titles for project investment	01/2026	12/2030	260 000,00 €		identification of an appropriate subsidy titles for project investment - check 1 time per year	Department of Investment and Development of NB CERRWM
			public tender for a contractor					public tender for a contractor	Department of Investment and Development of NB CERRWM
			supervision of construction implementation					supervision of construction implementation	Department of Investment and Development of NB CERRWM
								construction implementation	CERRWM
Action No. 5 – Applying requirements for the implementation of rainwater management for new buildings and renovations as part of building permits in Novy Bydzov									
5. Implementation of RWM in Novy Bydzov	applying the principle of using rainwater on the builder's land in new construction and in the reconstruction of buildings	Department of Construction and Environment of NB	supervision of permitting new buildings and renovations of buildings	06/2026	consistently	for buildings owned by the city	to make maximum use of subsidy titles	approving the project documentation of the construction	Environmental department of NB, Královéhradecká provozní a.s. - sewerage system operator
						private projects	costs covered by the investor	checking compliance with rules	CERRWM

3. Conclusion

The MAURICE project enabled the city of Novy Bydzov to initiate adaptation measures to mitigate the impacts of climate change on the city's water management.

To implement rainwater management in the city of Novy Bydzov, an action plan was developed with the help of the MAURICE project.

The action plan for the implementation of functional rainwater management consists of 5 basic adaptation measures, which were developed by the MAURICE project team and adopted by the management of the city of Novy Bydzov for the next period.


Město Nový Bydžov

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For the further implementation of the principles of sustainable rainwater management, the MAURICE project developed an action plan and strategy for its implementation (O.1.2 Transnational Water Management strategy and action plans for the six municipalities /regional areas considered by the project) and the city of Novy Bydzov will strive to implement this plan in the future.

Date: 19.6.2026

Signature and stamp:

Město NOVÝ BYDŽOV

Figure No.7: Confirmation of commitment to implement adaptation measures signed by the mayor of Novy Bydzov

Interreg CENTRAL EUROPE

Co-funded by the European Union

MAURICE

Action plan

Pilot area Varaždin

Version 1

04 2026

1. Preparing the ground for adaptation

The Varaždin aquifer is a significant water resource for the public water supply needs of the city of Varaždin. Within the aquifer area, there are three public water supply wellfields: Vinokovščak, Bartolovec, and Varaždin.

Agricultural activity is highly developed in the Varaždin aquifer area, partly consisting of conventional agricultural production and partly of livestock farms. This has a negative impact on the groundwater quality of the aquifer. As a result, the Varaždin wellfield has been excluded from the public water supply system due to the adverse effects of agriculture, specifically elevated nitrate concentrations in groundwater.

Monitoring of nitrate concentrations in groundwater has shown that nitrate levels vary depending on hydrological conditions. After heavy rainfall events, partial dilution of nitrate concentrations occurs. One of the objectives is to regulate agricultural production, while another important goal is to increase in-situ infiltration, which contributes to the dilution of nitrate concentrations in groundwater.

Figure 1. Nitrates monitoring

The wastewater and stormwater drainage system is combined, with all flows directed to a wastewater treatment plant with a capacity of only 215 l/s. When inflows exceed this capacity, excess water is discharged via overflow directly into the Drava River. This mainly occurs during the initial stages of heavy rainfall, when most of the excess water that cannot infiltrate directly into the ground enters the public drainage system, and a large portion of untreated wastewater is discharged directly into the Drava River.

The introduction of green – blue infrastructure (GBI) reduces the negative impact of intense rainfall on the public drainage system by retaining the first flush of stormwater, enabling its later use or infiltration into the aquifer, thereby contributing to the dilution of nitrate concentrations in groundwater.

The key policy framework for the action plan includes the Water Framework Directive, the Groundwater Directive, the Nitrates Directive, and the Urban Wastewater Treatment Directive. An important national reference is also the Ordinance on Conditions for Determining Sanitary Protection Zones of Water Sources (Official Gazette 66/11, 47/13).

The target groups at the national and regional levels include the water management agency in the Republic of Croatia – Croatian Waters, as well as the State Inspectorate of the Republic of Croatia, responsible for strict monitoring and inspection of potential polluters.

At the local level, the target groups include the municipal company responsible for water supply and sewerage management VARKOM, the municipal company for green area management PARKOVI, the City of Varaždin through its departments involved in preparing legislation related to the implementation of green and blue infrastructure, water supply, drainage, and spatial planning, as well as designers and planners.

2. Assesing climate change risks and vulnerabilities

Climate models for the wider Varaždin area indicate relative changes in air temperature and total precipitation expected in the coming period. According to climate models up to 2024, with projections to 2070, air temperature is expected to increase by about 1.5 °C (RCP2.6) to more than 2 °C (RCP8.5).

Precipitation is expected to show seasonal variability, with an increase in total precipitation during the winter period of around 5 % for continental Croatia. During summer, a decrease of 10 – 20 % is expected, while in autumn total precipitation is projected to vary between + 5 % and − 5 %. An increased frequency of extreme precipitation events is also expected, characterized by very high – intensity rainfall, which can lead to surface runoff problems, urban flooding, and significant pressure on public drainage systems.

The hydropower system on the Drava River (HPP Varaždin, HPP Čakovec, HPP Dubrava) has a significant influence on groundwater levels in the Varaždin aquifer, maintaining them relatively stable despite climate change. The aquifer is primarily recharged by the Drava River and associated reservoirs, which contributes to this stability.

Figure 2. Chanel to HPP Čakovec

Negative impacts of climate change are expected to include reduced infiltration of precipitation into groundwater, increased surface runoff, and greater pressure on public drainage systems.

For the Varaždin aquifer area, a numerical groundwater model has been developed, enabling the simulation of various climate change adaptation scenarios, such as the implementation of green and blue infrastructure and in-situ infiltration of roof runoff. The model has also been used to simulate nitrate transport, identifying some of the causes of elevated nitrate concentrations in the aquifer.

Adaptation objectives are divided into two main components: the first is controlling the mass of pollutants (e.g., nitrates) entering groundwater, and the second is controlling the volume of precipitation that recharges groundwater, as well as the pathways through which this water infiltrates and reaches the aquifer.

3. Identifying adaptation options

Climate change adaptation options may include “soft” measures, such as effective system management (e.g., introducing flexible working hours during heatwaves) or promoting the construction of climate-resilient buildings as part of urban planning. Technical, or “grey,” measures involve engineering interventions to protect urban areas (e.g., raising flood protection levees or increasing the capacity of public drainage systems), while ecological, or “green,” measures include the implementation of green infrastructure to manage runoff and influence the urban microclimate.

Adaptation options for urban water management in the city of Varaždin have been identified in two main ways:

- the implementation of GBI for rainwater reuse in urban areas, aimed at reducing the risk of urban flooding and alleviating pressure on the public drainage system,
- in-situ infiltration of rooftop runoff into the ground, to reduce pressure on the public drainage system and to dilute pollutants in the aquifer.

The reuse of rainwater is encouraged for all new developments, as well as for the renovation and adaptation of existing buildings and urban surfaces.

Figure 3. Public parks in Varaždin

4. Asessing and selecting adaptation options

The selection and evaluation of spatial planning regulation elements (RE) for the City of Varaždin have been carried out within a structured analytical framework aimed at supporting climate change (CC) resilient restoration of groundwater (GW) quality. The Varaždin aquifer is characterized by high permeability and strong hydraulic interaction with surface water bodies, including the Drava River system and associated hydropower accumulations. Such hydrogeological conditions increase the vulnerability of groundwater to diffuse and point – source pollution, particularly from agricultural activities, urban runoff, and insufficiently treated wastewater.

The identification of relevant regulation elements is based on a comprehensive review of the applicable spatial planning and regulatory framework, including the Spatial Development Plan of the City of Varaždin, the Spatial Plan of Varaždin County, and the Regulation on the Establishment of Sanitary Protection Zones of Water Sources (OG 55/02). These documents define land – use restrictions, protection zones, and infrastructure requirements relevant for groundwater protection. The assessment is further supported by hydrogeological studies on wellfield protection, groundwater quality monitoring data, and ongoing infrastructure investments, notably the Varaždin agglomeration project.

In order to ensure a transparent and consistent evaluation of heterogeneous RE's, a multi – criteria analysis (MCA) approach has been applied. MCA is considered an appropriate methodological tool in this context, as it enables the systematic comparison of measures differing in scope, function, and level of implementation, while integrating both expert judgment and available empirical evidence.

The evaluation framework is based on four core criteria:

- Identification of relevant RE, referring to the Land – use regulation and zoning, infrastructure regulation and technical measures, and ecosystem – based RE's;
- Definition of evaluation criteria, reflecting the extent to which the RE enhances the system's ability to cope with climate-induced pressures, including extreme precipitation events, flooding, and drought conditions through effectiveness in reducing contaminant pressures and contribution to CC resilience;
- Feasibility and enforceability, scoring approach considering legal, institutional, technical, and socio-economic aspects that influence the practical implementation and compliance within the existing planning system;
- Synergy with natural attenuation processes, assessing the extent to which the RE supports or enhances natural filtration, retention, and degradation processes in the soil – aquifer system.

Each RE is assessed against the defined criteria using a qualitative scoring system (high, medium, low), which allows for a consistent and transparent comparison across different categories of measures. The use of qualitative scoring is justified by the limited availability of harmonized quantitative data and the need to maintain methodological flexibility within the spatial planning context.

The results of the MCA are synthesized in an evaluation matrix, which provides the basis for identifying priority RE's for implementation and further development. In the Varaždin case, particular importance is attributed to measures related to the enforcement of sanitary protection zones, improved regulation of land use in groundwater recharge areas, and the upgrading of wastewater collection and treatment systems. These are complemented by ecosystem – based approaches and the need for enhanced coordination with hydropower management practices.

Overall, the applied MCA provides a robust and policy – relevant framework for the evaluation and prioritization of spatial RE's, ensuring alignment with CC adaptation objectives and contributing to the long – term protection and restoration of groundwater quality in the Varaždin area.

5. Implementing adaptation

All results of the MAURICE project will be available for practical application in the upcoming management period. During the next revision of the spatial plan, as well as the adoption of the Green and Blue Infrastructure Plan, they will serve as a professional basis with identified and validated improvements for upgrading legislation, particularly in relation to public drainage systems, groundwater management, and the implementation of green and blue infrastructure.
In the Varaždin pilot area, within the MAURICE project, the following reports and results have been developed and institutionally integrated:

- Output 4.2: Pilot Action design and implementation for Varaždin: Test and demonstration of a climate adaptation monitoring and warning system for groundwater quality restoration in heavily modified water regime areas – linked to D.4.3.2: Report on testing the effects on groundwater quality through optimization of infiltration
- Deliverable D.4.3.3: Regulatory elements for resilient groundwater quality in areas of heavily modified water regimes
- Deliverable D.4.4.1: Optimization of urban drainage and resilience of groundwater quality (booklet) – linked to Output O.4.3: Use of the infiltration capacity map from field investigations for planning, permitting, and decision-making
- Deliverable D.4.4.2: Survey of urban drainage efficiency for groundwater quality resilience – linked to Output O.4.4: Assessment of urban water mass flows and contaminants to define resilient drainage and infiltration targets

The City of Varaždin envisions the uptake of these results as a key component in strengthening local climate adaptation capacity, particularly in the field of groundwater quality protection and sustainable urban water management. The developed monitoring systems, regulatory elements, and planning tools can be systematically applied in municipal planning processes, infrastructure development, and environmental management practices.

Furthermore, the above – mentioned outputs and deliverables have been incorporated into:

- Guidelines adopted through an official conclusion of the Mayor, ensuring their immediate applicability in administrative and planning procedures; and
- The new Blue-Green Infrastructure (BGI) Plan of the City of Varaždin, which is currently undergoing public consultation and will be submitted for adoption by the City Council.

The BGI Plan includes concrete measures inspired by the MAURICE project results, such as the integration of nature-based solutions (e.g., rain gardens in future parks planned by the City), improved urban drainage systems, and the use of project deliverables to guide spatial planning and development decisions.

REPUBLIKA HRVATSKA
VARAŽDINSKA ŽUPANIJA
GRAD VARAŽDIN
www.varazdin.hr · e-mail: varazdin@varazdin.hr
Gradonačelnik

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Varaždin, 20.04.2026.

FORMAL STATEMENT ON THE UPTAKE OF PROJECT RESULTS

Project acronym and number: MAURICE – CE0100184
Organisation: PP11 City Municipality Varaždin

Subject: Uptake of project outputs and deliverables within the MAURICE project

The City of Varaždin hereby confirms the uptake and institutional integration of the following outputs and deliverables developed within the MAURICE project:

- **Output 4.2:** *Pilot Action design and implementation for Varaždin: Test and demonstration of climate adaptation monitoring warning system for groundwater quality restoration in heavily modified water regime areas - link* ***to D.4.3.2*** *Report from testing the effects on GW quality by optimization of infiltration*
- **Deliverable D.4.3.3:** *Regulation elements for resilient groundwater (GW) quality in areas of heavily modified water regimes*
- **Deliverable D.4.4.1:** *Optimization of urban drainage and resilience of groundwater quality (booklet) - link to* ***Output O.4.3****: Use of the infiltration capacity map from field investigation for planning, consent and decision-making*
- **Deliverable D.4.4.2:** *Survey of urban drainage efficiency for resilience of groundwater quality - link to* ***Output O.4.4:*** *Surveying urban water mass flows and contaminants to set resilient drainage and infiltration targets*

The City of Varaždin envisions the uptake of these results as a key component in strengthening local climate adaptation capacity, particularly in the field of groundwater quality protection and sustainable urban water management. The developed monitoring systems, regulatory elements, and planning tools may be systematically applied in municipal planning processes, infrastructure development, and environmental management practices.

Furthermore, above-mentioned outputs and deliverables have been incorporated into:

- **Guidelines adopted through the official conclusion of the Mayor**, ensuring their immediate applicability in administrative and planning procedures; and
- **The new Blue-Green Infrastructure (BGI) Plan of the City of Varaždin**, which is currently in the process of public consultation and will be considered for adoption by the City Council.

The BGI Plan includes concrete measures inspired by the MAURICE project results, such as the integration of nature-based solutions (e.g. rain gardens in future parks planned by the City), improved urban drainage systems, and the use of project deliverables to guide spatial planning and development decisions.

The City of Varaždin is committed to maintaining and further developing these strategies and solutions beyond the duration of the MAURICE project. The results will be embedded in long-term planning documents, regulatory frameworks, and future infrastructure investments, ensuring their sustainability and continued impact.

Finally, the City of Varaždin confirms that all adopted strategies, action plan, and solutions are the result of joint work and cooperation within the MAURICE project.

Neven Bosilj, Ph. D.
Mayor
City of Varaždin

REPUBLIKA HRVATSKA GRAD VARAŽDIN Gradonačelnik 1 VARAŽDIN VARAŽDINSKA ŽUPANIJA

NO.	MEASURES	SHORT DESCRIPTION	ROLES & RESPONSIBILITIES	TIMEFRAME	FINANCE & RESOURCES	MONITORING
1	REDUCTION OF SURFACE RUNOFF					
1-1	Cover deposits map / infiltration capacity map	Cover deposits / infiltration capacity map for planning runoff management and BGI (Blue-Green Infrastructure) placement and potential connections with the GUP (General Urban Plan)	**Lead:** UNIZG-GFV (P10) depending on available future project opportunities and the scope of follow-up activities. **Support/use:** City of Varaždin (P11), Sjever-DAN d.o.o., VARKOM d.o.o, Parkovi d.o.o.	Available from MAURICE project use 2026-2030; update when new field data are available	Depending on the scope of implementation UNIZG-GFV (P10) expert/GIS resources and City of Varaždin (P11) planning resources; through available institutional resources, local funding opportunities, possible EU/national funds opportunities	**Indicators:** layer used in GUP, BGI Plan and project documentation; updates recorded
1-2	Monitoring of GWL	Use and periodic interpretation of groundwater-level data and possible analysis of the influence of the Drava / HPP system on groundwater dynamics	**Lead/data holders:** Croatian Waters and HEP depending on their internal monitoring plans **Interpretation/use:** UNIZG-GFV (P10), City of Varaždin (P11), VARKOM d.o.o.	Continuous monitoring and annual or periodic review of data; according to Croatian Waters and HEP monitoring plans	Existing monitoring network; no major new investment foreseen. Depending on the scope of implementation, UNIZG-GFV (P10) / City of Varaždin (P11) expert/staff time	**Indicators:** groundwater-level datasets reviewed; relation to precipitation / river regime considered in planning
1-3	Monitoring of precipitation amounts	Monitoring and use of precipitation and climate indicators for stormwater and BGI planning	**Lead/data holder:** DHMZ, depending on their internal monitoring plans **Analysis/use:** UNIZG-GFV (P10), City of Varaždin (P11), Sjever-DAN d.o.o., VARKOM d.o.o.	Continuous monitoring and annual or periodic update of data; according to DHMZ monitoring plans	Existing meteorological datasets; data access where needed. Depending on the scope of implementation, UNIZG-GFV (P10) / City of Varaždin (P11) expert/staff time	**Indicators:** extreme precipitation indicators and trends used in drainage and spatial-planning decisions
1-4	Implementation of BGI regarding Sustainable Urban Drainage Systems (SuDS)	Implementation of BGI/SuDS to retain, infiltrate or reuse stormwater: rain gardens, bioswales, permeable pavements, green strips,	**Lead:** City of Varaždin (P11) **Support:** UNIZG-GFV (P10), VARKOM d.o.o., Parkovi d.o.o., Sjever-DAN d.o.o., designers, contractors	Phased implementation 2026-2030 and beyond, depending on available funding and future project opportunities	Depending on available City of Varaždin (P11) budget and future project opportunities: city departments for design, construction and maintenance services; VARKOM d.o.o. / Parkovi	**Indicators:** number/area of BGI elements; estimated retained/infiltrated volume; reduced runoff from public surfaces

NO.	MEASURES	SHORT DESCRIPTION	ROLES & RESPONSIBILITIES	TIMEFRAME	FINANCE & RESOURCES	MONITORING
		retention areas and rooftop runoff reuse			d.o.o. available budgets; EU/national funds opportunities; developer contributions where applicable	
2	**ENABLE DEGRADATION AND DILUTION OF POLLUTANTS**					
2-1	Monitoring of nitrate concentrations at wellfield sites	Monitoring of nitrate concentrations at public water-supply wellfields and use of results for protection measures	**Lead:** VARKOM d.o.o. **Support/use:** UNIZG-GFV (P10), City of Varaždin (P11), Croatian Waters	Continuous, according to VARKOM d.o.o. monitoring plans	Operational/laboratory monitoring via available VARKOM resources; national water-monitoring resources where applicable	**Indicators:** nitrate trends and exceedance frequency at wellfields; datasets shared for planning/reporting Responsible: VARKOM and GFV
2-2	Monitoring of nitrate concentrations across the aquifer	Aquifer-wide nitrate assessment, mapping and modelling support, including links with agricultural areas and other diffuse sources	**Lead:** UNIZG-GFV (P10) **Support:** City of Varaždin, VARKOM d.o.o., Croatian Waters, other data holders	2026-2030 and beyond, depending on research / project cycles and available funding	Research, GIS/modelling and field/lab resources; possible GFV DIMRAN NPOO project / resources funding; additional competitive funds if available	**Indicators:** updated vulnerability/nitrate maps, monitoring summaries and modelling outputs prepared and communicated
2-3	Implementation of BGI for possible degradation/dilution of pollutants	Targeted in-situ infiltration and rainwater reuse where hydrogeologically appropriate, with pretreatment where needed, to support recharge and pollutant dilution without increasing groundwater risk	**Lead:** City of Varaždin (P11) **Support:** UNIZG-GFV (P10), VARKOM d.o.o., Parkovi d.o.o., designers, property owners	Phased implementation 2026-2030 and beyond, depending on City of Varaždin (P11) planning cycle and available funding	Hydrogeological assessment, design, comprehension and maintenance expertise; municipal/EU funds; possible private investment and incentives where adopted	**Indicators:** projects include infiltration safety criteria; groundwater-quality trends checked at relevant monitoring points
3	**PREVENTION OF SEWER SYSTEM OVERLOAD**					
3-1	Implementation of BGI	BGI and rainwater disconnection/retention to reduce inflow to the combined sewer system during intense rainfall	**Lead:** City of Varaždin (P11) and VARKOM d.o.o.	Phased implementation 2026-2030 and beyond, depending on City of Varaždin (P11) planning cycle and available funding	Depending on the scope of implementation: planning, design, construction, operation and maintenance costs; possible City of Varaždin (P11) and VARKOM d.o.o. budgets; possible EU/national funds; developer contributions	**Indicators:** estimated runoff volume retained/reused; number of disconnected or partly disconnected surfaces; sewer-overload/overflow records

NO.	MEASURES	SHORT DESCRIPTION	ROLES & RESPONSIBILITIES	TIMEFRAME	FINANCE & RESOURCES	MONITORING
4	**SPATIAL-PLANNING AND IMPLEMENTATION FRAMEWORK**					
4-1	Integration of MAURICE guidelines	Integration of MAURICE guidelines for sustainable stormwater management into the new GUP, BGI Plan and relevant municipal planning procedures	**Lead:** City of Varaždin (P11) **Support:** UNIZG-GFV (P10)	Possible by 2030, in line with the City of Varaždin (P11) planning cycle and GUP integration	Depending on the scope of implementation City of Varaždin (P11) planning / legal staff and possible planning budget for technical-assistance funds; UNIZG-GFV (P10) expert support; external planners	**Indicators:** guidelines referenced in plans/procedures; BGI requirements included in planning and permitting criteria
4-2	Sustainable drainage and BGI elements	Preparation of technical standards and maintenance protocols for sustainable drainage and BGI elements	**Lead:** City of Varaždin (P11) **Support:** UNIZG-GFV (P10), Sjever-DAN d.o.o., VARKOM d.o.o., Parkovi d.o.o., urban planners	Phased implementation 2027-2030 depending on City of Varaždin (P11) planning cycle and available funding	Technical, legal and maintenance expertise; City of Varaždin (P11) / VARKOM d.o.o. / Parkovi d.o.o budgets; external services where needed	**Indicators:** technical guidance adopted; maintenance responsibilities and inspection frequency defined
4-3	Public and private BGI implementation	Development of financing and incentive models for public and private BGI implementation and maintenance	**Lead:** City of Varaždin (P11)	Phased implementation 2027-2030; apply in future projects, depending on available funding	Possibly City of Varaždin (P11) administrative and technical staff; EU/national calls; possible fee reductions/incentives; private co-financing	**Indicators:** financing options identified; number/value of supported BGI projects; assists included in local procedures where feasible
5	**EDUCATION AND CAPACITY BUILDING**					
5-1	Education and communication	Education and communication for local administration, professionals, citizens and property owners on BGI implementation and maintenance	**Lead:** City of Varaždin (P11) **Support:** UNIZG-GFV (P10), VARKOM d.o.o., Parkovi d.o.o., Sjever-DAN d.o.o. and other possible stakeholders	Continuous 2026-2030 and beyond according to City of Varaždin (P11) planning cycle and available funding	Expert UNIZG-GFV (P10) lecturers, communication staff, workshops and public materials; City of Varaždin (P11) / project dissemination resources; EU/national funds where available	**Indicators:** number of workshops/events, participants and materials; feedback collected; examples of uptake

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MAURICE

Deliverable D.1.4.1

Action plan Ljubljana

Final version

05 2026

Report D.1.4.1

Action plan Ljubljana: Climate-resilient urban drainage – Ljubljana

Pilot action WP4: RESILIENCE TO CLIMATE CHANGE IMPACTS ON URBAN GROUNDWATER QUALITY THROUGH SPATIAL PLANNING ELEMENTS

Table of content

1. PREPARING THE GROUND FOR ADAPTION

Strategy for climate resilience of groundwater quality in the city

Resilience is functionally defined as the ability to prepare for, respond to, and adapt to climate impacts, aiming to protect people, the economy, infrastructure, and natural systems[1].

The long-term objective of water policy is to ensure high-quality water in sufficient quantities for the entire population and the ecosystem.

Groundwater is a natural resource stored in aquifers beneath the city surface. It is replenished by the infiltration of precipitation and surface water into the subsurface. Climate resilience of groundwater refers to its capacity to recharge continuously and maintain its multifunctional role within the natural system, which is essential for developing a circular economy.

Groundwater is resilient to climate change if the functional urban area (the city core and its hinterland) is large enough to provide sufficient water for its population while enabling the degradation and dilution of discharges, so that cities and downstream ecosystems have equal opportunities, and good water status is not maintained at the expense of upstream cities.

Special purpose – legal frameworks

The risks and vulnerabilities of groundwater are in fact managed only by transferring the boundaries of the natural system into the agreed boundaries of parcels or other units of the spatial plan. Within these boundaries, the spatial planning elements needed by planners and designers to ensure the resilience of groundwater quality and quantity to climate change must be provided.

Key legal bases – groundwater, urban wastewater

The key basis and framework for the action plan are the Water Framework Directive, the Groundwater Directive, the Urban Waste Water Treatment Directive, Act on the Supply of Drinking Water and the Collection and Treatment of Municipal Wastewater, the Regulation on the Status of Groundwater, the Decree on the Emission of Substances and Heat from Wastewater Discharges into Waters and Public Sewerage Systems, the Municipal Spatial Plan of the City of Ljubljana – Implementation Part, and the Technical Regulations for Sewerage Systems.

The Urban waste water treatment directive[2] includes two objectives that establish a direct link between water resources management and wastewater management: “Climate change adaptation through stormwater management” and “Strengthening the circular economy by promoting the reuse of treated water.” In this context, it is important to emphasise that the circular economy is future-oriented and not about repeating outdated approaches. Its core is not the increasingly advanced treatment of already polluted water, but the timely prevention of discharges, the reduction of disposal needs, and the interception of substances before they enter the environment. Only with such an understanding – by reducing pollution at the source and maximising the reuse of substances – can the circular economy become an effective development framework. Therefore, it is essential that this message is clearly and decisively communicated at the political level and becomes a cornerstone of future environmental policies.

Target groups – development and users

The main target groups are water resource managers, providers of public wastewater treatment and sewerage services, designers of stormwater drainage systems, planners and preparers of municipal spatial plans and consent-giving authorities, as well as preparers of environmental reports, assessments, and environmental impact assessments.

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[1] About climate adaptation and resilience - European Commission (23. 3. 2026)

[2] Urban Wastewater Treatment Directive – UWWTD, revised, 1. 1. 2025

Stakeholder analysis – regional interest group

Key stakeholders include the public utility company Vodovod Kanalizacija Snaga, the Ljubljana Urban Planning Institute, the City of Ljubljana – Urban Planning Department, the Urban Planning Institute of the Republic of Slovenia, ZaVita, PNZ Consulting and Design, the Faculty of Civil and Geodetic Engineering – Institute of Public Health Engineering, the Faculty of Civil and Geodetic Engineering – Chair of Geotechnics, the Slovenian Water Agency, the Institute of the Republic of Slovenia for Nature Conservation, the Joint Environmental Protection Service – City of Kranj, and the Geological Survey of Slovenia – Department of Hydrogeology and Groundwater.

2. ASSESING CLIMATE RISKS AND VULNERABILITIES

2.1 Key climate risk

Modelling the impacts of projected climate change up to the year 2100 reveals potentially diverse changes in individual components of the hydrological cycle, including groundwater. Changes are expected in groundwater recharge, flow through the aquifer, flow directions, and groundwater levels. These changes will also be reflected in variations in pollutant concentrations and types, as well as in shifts of pollutant pathways towards other abstraction points, water resources, and habitats. Alterations in groundwater levels may affect the yield of abstraction points, stability conditions in foundation soils, and construction conditions.

2.2 Impacts on Ljubljana

Regional climate change will alter groundwater flow directions in Ljubljana by approximately ±3°. Surface runoff will contribute a larger proportion to groundwater recharge. Groundwater levels may rise by up to 7 m in some locations, in some areas approaching or reaching building foundations, while at certain abstraction sites groundwater levels may decrease by up to 2 m.

With an increasing proportion of surface runoff infiltration, alongside greater surface sealing and runoff from built-up and paved areas, the natural retention capacity for pollutants will decrease. The potential for pollutant degradation and dilution will also be reduced. Consequently, the previous trend of improving water quality, observed from 2000 to 2020, would reverse, leading to a deterioration in water quality. This trend is already indicated by monitoring results after 2015.

Groundwater quality may become even more vulnerable due to changes in flow directions and rising groundwater levels. Altered groundwater flow directions can redirect more polluted flows from current industrial sources, as well as legacy pollution, towards the main drinking water abstraction sites. Such a flow pattern developed in the past during peak industrial activity and caused severe pollution of the main pumping station at Kleče. Rising groundwater levels may also mobilise legacy contamination from past pollution that currently remains above the groundwater table.

The impacts of current changes in groundwater flow directions and levels are now visible in relatively small changes in concentrations, particularly in the case of hexavalent chromium. This contaminant occurs dynamically in localised hotspots in groundwater at concentrations exceeding quality standards. The occurrence and dynamics of these concentrations reflect the combined influence of legacy pollution and current industrial use, including losses of industrial wastewater from sewer systems. These involve pollutant uses that are only partly controlled and represent typical multi-point sources whose magnitude and location change over time.

Such conditions already threaten the security and resilience of the drinking water supply and are difficult to manage under current circumstances, while also limiting the development of economic activities.

2.3 Adaptation objective

Adaptation objectives are divided into three sets. The first focuses on controlling the mass of pollutants entering groundwater. The second on controlling the volume of stormwater that recharges groundwater and the manner in which these waters infiltrate the subsurface and reach groundwater. The third is reduction of the inflow of relatively clean stormwater into the public sewer system, thereby decreasing environmental pollution caused by frequent combined sewer overflows.

Together, these sets will help ensure that, despite increasing pressures from urban activities such as substance use, emissions, land take, and work areas, losses of substances and impacts on groundwater quality can be relatively reduced over time.

3. IDENTIFYING ADAPTATION OPTIONS

3.1 Basic adaptation measure

The basic adaptation measure is the directed infiltration of stormwater from urban surfaces for groundwater recharge. The measure is implemented on surfaces and in a manner that enables effective infiltration while not causing adverse effects on slope stability conditions or water ingress into buildings.

To enable the infiltration of stormwater for groundwater recharge, sufficient infiltration areas must be provided in relation to the infiltration capacity of the land, along with appropriate treatment depending on the type of drained surfaces (roof, residential, work, and traffic surfaces). At the same time, adequate retention volumes must be ensured for retaining and reducing peak stormwater flows so that the water can infiltrate continuously.

The infiltration of stormwater for the purpose of groundwater recharge is encouraged both for all new interventions and spatial arrangements and in the renovation and adaptation of existing buildings, surfaces, and arrangements.

One of the important conditions for infiltration is uncontaminated soil and subsoil. At the same time, infiltration is promoted where greater recharge of groundwater quantity and quality is needed.

To guide infiltration priorities, the contamination of soil and subsoil, as well as trends in pollutant loads in groundwater, are also monitored and tracked.

3.2 Potential for scaling up and synergies

The synergy between groundwater management and stormwater wastewater management is multifaceted.

The synergy of infiltration adaptation measures is strong with measures aimed at maintaining the favourable status of ecosystems and reducing the impacts of drought or water scarcity. Infiltration contributes to preventing soil water deficits or soil drying in urban areas and consequently to reducing the need for irrigation water. Infiltration and retention measures also have synergistic effects with self-sufficiency measures and with reducing the need to use water from the public water supply system or other water resources.

The planning of infiltration systems is interdependent with the planning of stormwater drainage in the city. Where infiltration capacity is good, only overflows to drainage channels or spreading areas are required for extreme rainfall events. Where infiltration capacity is lower, discharges to drainage channels or stormwater sewers are also required. Where the capacity of drainage channels or sewer systems is lower, larger retention volumes are required so that the peak flow of a storm event can be temporarily retained and then slowly released.

Taking into account the loading of the public sewerage system, an appropriate economic balance is also sought between the required retention volume at the level of the building plot or spatial planning unit (depending on the level of assessment and planning) and any permitted discharge and overflow. This balance can be an incentive for the owner if the required retained water volume is equivalent to the water needs on the land outside and inside the building. For the community, it is appropriate that the owner manages on their own land the excess stormwater runoff generated by the development designed on that land.

Adaptation is effective if permitted discharges to different surfaces can be defined comprehensively and as uniformly as possible (infiltration, surrounding surfaces, retention facilities, watercourses, other drainage channels, and only exceptionally sewerage systems). Allowable overflows should provide protection against flooding with a frequency of 1-x in 30 years. In this way, the greatest possible synergy is sought between the measures of different sectors that manage the recipients of discharges and overflows.

Infiltration and retention are among the techniques for ensuring the resilience of stormwater drainage in the city and, at the same time, among the key techniques for ensuring the resilience of groundwater quality to climate conditions.

The determination of priorities for infiltration and retention is linked to the determination of priorities for the development of sewerage systems and spreading areas for extreme rainfall events in the city.

4. ASSESSING AND SELECTING ADAPTATION OPTIONS

4.1 Assessment criteria

The concept of the Action Plan was discussed with stakeholders and representatives of the target groups within the regional interest group (22 October 2024). Based on an analysis of the current situation and risks, the concept identified a range of possible measures to improve the climate resilience of stormwater drainage in the area of the City of Ljubljana (MOL). From the perspective of synergies between drainage resilience and groundwater quality, the measures focused on five significant management issues (SMIs):

1. enabling groundwater recharge,
2. maintaining groundwater levels,
3. ensuring sufficient dilution of pollutants,
4. balancing surpluses and deficits of water mass,
5. preventing overloading of the sewerage system.

The discussion highlighted 21 different issues or aspects that could be further clarified and could receive greater support in practice or in regulations regarding the drainage of stormwater wastewater in the city. These issues relate to incentives at the national level, incentives at the local level, separate requirements for stormwater runoff for new and existing users, environmental aspects, the quality of drinking water resources, and consents and opinions in support of the public interest.

For each issue, more than 40 guidance measures were formulated based on the discussion and differing perspectives.

The criterion for selecting adaptation options and including them in the Action Plan was that the measure was identified as effective and feasible at the local level or within ongoing activities, with known cost sources and within a known time frame.

4.2 Result

The most effective and feasible measure identified was the preparation of an infiltration capacity map, together with guidelines for field permeability testing and an illustrative example of a retention–infiltration system under conditions of low infiltration capacity. The infiltration capacity map will provide a clear overview of the infiltration potential that can be expected in different parts of the city and of the drainage approaches that should be planned or ensured for a given spatial planning unit or building plot. The illustrative retention–infiltration system will enable direct insight into how such a facility behaves after construction, how its operation can be monitored, and what is important for its maintenance.

This is followed by adaptation measures that introduce consideration of limitations to infiltration due to natural conditions and are most concretely defined through the specification of different types of minimum requirements: minimum setback distances due to the impact of infiltration on groundwater levels and quality, minimum groundwater recharge, and a minimum share of land designated for infiltration. These are also the measures most directly linked to regulatory elements in spatial planning.

Third on the priority list is a set of measures for defining permissible discharges and overflows, planning drainage systems for the final state of development, documenting impacts, and carrying out comparative analyses of drainage resilience at the level of spatial planning units.

The final set of measures is directly related to the resilience of groundwater quality and introduces an approach for defining critical pollutant concentration values at which action must be initiated, as well as for defining target values for reducing losses of critical pollutants.

5. IMPLEMENTING ADAPTATION POLICES AND ACTIONS

Adaptation and response measures will be implemented through the publication and accessibility of data layers, illustrative examples, expert supporting materials, recommendations, guidelines, and approaches.

GIS data layers on infiltration capacity and infiltration constraints within the City of Ljubljana (COL) will be made available. User instructions and metadata descriptions will also be published.

Criteria for the acceptability of impacts on groundwater levels and concentrations of hazardous and other substances have already been adopted through the General Guidelines in the Field of Water Management (Slovenian Water Agency – DRSV, Guidelines for the Assessment of Impacts on Groundwater, January 2022). Requirements for minimum setback distances for infiltration systems are also linked to these criteria.

Guidance for planning stormwater drainage for the final state of development of spatial planning units was introduced in August 2024 through the General Guidelines in the Field of Water Management (DRSV – Instructions in Annex 8 of the General Guidelines). This is complemented by the guidance in D44, which provides more detailed information on planning for the final development state using the tools and outputs of the MAURICE project.

All outputs of the MAURICE project will be available and applied in practice in the next programme period. They will serve, at the next amendment of the Municipal Spatial Plan of the City of Ljubljana – Implementation Part (OPN MOL ID), as an established and tested expert basis for upgrading provisions, particularly Article 51 (construction of sewerage systems), Article 78a (groundwater), and Article 85 (landslide-prone and erosion-prone areas). The Spatial Development Status Map can also be upgraded.

Although MAURICE outputs address and provide recommendations and approaches for ensuring the resilience of groundwater quality and appropriate infiltration of stormwater according to its pollution load, they do not include the issue of stormwater treatment at the inflow to infiltration systems. This technology is addressed by MAURICE within Work Package WP3. For the Ljubljana area, especially within water protection zones, the role of soil, the pedological horizon, and its capacity to remove emerging pollutants and those related to the transition to electric mobility will need to be incorporated into stormwater drainage solutions.

6. MONITORING AND EVALUATING ADAPTATION

Monitoring of the implementation of adaptation is carried out by tracking the publication and availability for use of the products and tools listed in the table below (Table 1).

Monitoring and evaluation are carried out annually by the users (primarily JP VOKA SNAGA and GeoZS) until the next amendments to the Municipal Spatial Plan of the City of Ljubljana – Implementation Part (OPN MOL ID) or until the expiry of the five-year period.

JP VOKA SNAGA and GeoZS maintain and update the links and accessibility, and revise or upgrade them as necessary.

Evaluation of adaptation is carried out on the basis of the number of retention–infiltration systems, the area of land drained by infiltration, and the total runoff coefficient (Table 2).

The number of spatial planning units for which the envisaged drainage solution for the final state of area development is known is recorded, as well as the number of units for which a comparative resilience analysis has been carried out; this also enables a simplified procedure for obtaining consents.

The share of roof surfaces drained entirely to infiltration and the share of disconnected roof surfaces are also recorded.

Table 1. Indicators for monitoring the implementation of adaptation

ID	Adaptation implementation	Description	Publication	Link	Update
SMI-1	**ENABLING GROUNDWATER RECHARGE**				
1	Infiltration capacity map	Publication to support procedures	May 2026		
2	Recommendations for field permeability tests	Publication to support procedures			
3	Demonstration retention-infiltration facility	Established monitoring measurements	June 2025		
SMI-2	**MAINTAINING GROUNDWATER LEVELS**				
4	Minimum setback due to impacts on groundwater levels	Definition and publication of acceptability criteria			
5	Minimum vertical distance between the base of infiltration facilities and the highest groundwater level	Definition and publication of acceptability criteria			
6	Sensitivity of abstraction sites and buildings to changes in groundwater levels	Publication of assessments and monitoring recommendations			
SMI-3	**ENSURING DEGRADATION AND DILUTION OF POLLUTANTS**				
7	Minimum setback due to impacts on groundwater quality	Definition and publication of acceptability criteria			
8	Critical pollutant concentration values triggering adaptation measures	Definition and publication of acceptability criteria			
9	Target value for reducing pollutant losses	Publication of values and recommendations for determination			
10	Priority areas for restoring infiltration through infiltration systems	Publication of assessments and recommendations for identification			
11	Minimum infiltration requirements for groundwater recharge	Publication of assessments and recommendations for determination			
SMI-4	**BALANCING SURPLUSES AND DEFICITS OF WATER MASS**				
12	Recommendations for comparative drainage resilience analysis	Publication of recommendations for assessment			
13	Priority drainage measures for flood safety – by effectiveness for groundwater recharge	Publication of a decision-support overview table			
14	Register of infiltration systems for tracking effectiveness of measures	Publication of examples and key parameters			
SMI-5	**PREVENTING OVERLOADING OF THE SEWERAGE SYSTEM**				
15	Updated approach to defining permitted discharges into the sewer system	Publication of a selection of possible reference approaches			
16	Planning of drainage for the final state of development	Definition and publication of guidelines			
17	Requirements for integrated drainage solutions	Definition and publication of guidelines			
18	Drainage plan prior to issuing permits/consents	Publication of recommendations for an already established measure			
19	Share of land required for infiltration	Publication of recommendations			

Table 2. Indicators for evaluating adaptation

ID	Adaptation measures	Evaluation	Value	2027	2028	
1	Constructed retention-infiltration systems	Number				
		Area of drained surfaces				
		Total runoff coefficient Ψm				
		Share of infiltrated stormwater				
2	Drainage solution for the final state of development	Number of spatial planning units				
3	Comparative resilience analysis	Number of spatial planning units				
		Number of building plots				
4	Infiltration of clean roof runoff	Share of roof surfaces infiltrated				
		Share of disconnected roof surfaces				
5	Definition of permitted discharges and overflows	Share of OPN MOL area				
6						
	Groundwater pollutants		**Value**	**2030**	**2035**	
7	Diffuse pollution					
	Nitrate	Concentration (mean-max)				
	Nitrogen	Load				
8	Point-source pollution					
	Hexavalent chromium	Concentration (mean-max)				
		Load				
	Benzotriazoles	Concentration (mean-max)				
		Load				
	Pollutant with a spreading trend	Concentration (mean-max)				
		Load				
9	Implemented measures for critical pollutants	Share of pollutants				

7. ANNEXES

7.1 Regulations

List:

1. Urban Waste Water Treatment Directive (UWWTD – recast, adopted on 10 April 2024)
2. Water Act (Official Gazette of the Republic of Slovenia, Nos. 67/02, 2/04 – ZZdrl-A, 41/04 – ZVO-1, 57/08, 57/12, 100/13, 40/14, 56/15, 65/20, 35/23 – Constitutional Court Decision, and 78/23 – ZUNPEOVE)
3. CC.SI classification
4. Act on the Supply of Drinking Water and the Collection and Treatment of Municipal Wastewater (Official Gazette of the Republic of Slovenia, No. 21/25)
5. Regulation on the discharge and treatment of municipal wastewater (Official Gazette of the Republic of Slovenia, Nos. 98/15, 76/17, 81/19, 194/21 and 44/22 – ZVO-2)
6. Regulation on the emission of substances and heat from the discharge of wastewater into waters and public sewerage systems (Official Gazette of the Republic of Slovenia, Nos. 64/12, 64/14, 98/15, 44/22 – ZVO-2, 75/22 and 157/22)
7. Regulation on the emission of substances from the discharge of stormwater from public roads (Official Gazette of the Republic of Slovenia, Nos. 47/05 and 44/22 – ZVO-2)
8. Ordinance on the discharge and treatment of municipal and stormwater wastewater in the City of Ljubljana (Official Gazette No. 9/18)
9. Municipal Spatial Plan of the City of Ljubljana – Implementation Part (OPN MOL ID)
10. Project conditions for the discharge of stormwater runoff from areas of planned new developments, JP VOKA SNAGA d.o.o.

7.2 Action plan

Nr.	Action	Description	Resp.	Involved	Support	Start	End	Budget
SMI-1	**ENABLING GROUNDWATER RECHARGE**							
1	Infiltration capacity map	Publication to support procedures	GeoZS	JP VOKASNAGA	MOL	Sept-22	Jun-26	JPVOKASNAGA, MAURICE
2	Recommendations for field permeability testing	Publication to support procedures	GeoZS	JP VOKASNAGA	MOL	Mar-23	Jun-26	MAURICE
3	Demonstration retention-infiltration field	Established measurements for monitoring effectiveness	JP VOKASNAGA	GeoZS	MOL	Mar-23	Jun-26	MAURICE
SMI-2	**MAINTAINING GROUNDWATER LEVELS**							
4	Minimum setback due to impacts on groundwater levels	Definition and publication of acceptability criteria	DRSV	GeoZS		/	Jan-22	General guidance
5	Minimum vertical distance between the base of infiltration facilities and the highest groundwater level	Definition and publication of acceptability criteria	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
6	Sensitivity of abstraction sites and buildings to changes in groundwater levels	Publication of assessments and monitoring recommendations	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
SMI-3	**ENSURING DEGRADATION AND DILUTION OF POLLUTANTS**							
7	Minimum setback due to impacts on groundwater quality	Definition and publication of acceptability criteria	DRSV	GeoZS		/	Jan-22	General guidance
8	Critical pollutant concentration values triggering adaptation measures	Definition and publication of acceptability criteria	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
9	Target value for reducing pollutant losses	Publication of values and recommendations for determination	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
10	Priority areas for restoring infiltration through infiltration systems	Publication of assessments and recommendations for determination	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
11	Minimum infiltration requirements for groundwater recharge	Publication of assessments and recommendations for determination	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
SMI-4	**BALANCING SURPLUSES AND DEFICITS OF WATER MASS**							
12	Recommendations for comparative drainage resilience analysis	Publication of assessment recommendations	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
13	Priority drainage measures for flood safety - by effectiveness for groundwater recharge	Publication of a decision-support overview table	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
14	Register of infiltration systems for monitoring effectiveness of measures	Publication of examples and key parameters	GeoZS	JP VOKASNAGA		Mar-23	Jun-26	MAURICE
SMI-5	**PREVENTING OVERLOADING OF THE SEWERAGE SYSTEM**							
15	Updated approach to defining permitted discharges into the sewer system	Publication of a selection of possible reference approaches	JP VOKASNAGA		GeoZS	Mar-23	2028 ?	MOL
16	Planning of drainage for the final state of development	Definition and publication of guidelines	DRSV	GeoZS			Aug-24	General guidance
17	Requirements for integrated drainage solutions	Definition and publication of guidelines	DRSV	GeoZS			Aug-24	General guidance
18	Drainage plan prior to issuing permits/consents	Publication of recommendations for an already established measure	DRSV	GeoZS	JP VOKASNAGA		Aug-24	General guidance
19	Share of land required for infiltration	Publication of recommendations	GeoZS	JP VOKASNAGA	MOL	Mar-23	Jun-26	MAURICE